Advertising for cariogenic food and drinks: A cross-over randomised controlled trial investigating the effect of cariogenic food and drink advertising on children's dietary intake.

This Dissertation is in partial fulfilment of the Degree Doctorate in Dental Sciences of the University of Liverpool

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2 Abstract

Aim: The aim of this study was to investigate whether 8-10 year olds make different food and drink choices after they have been exposed to advertisements for high sugar (cariogenic) food and drink items compared with non-food advertisements. The secondary aims of this study were, firstly, to investigate the relationship between the children's response to advertising content and their caries experience, weight status and socioeconomic status. Secondly, to investigate any relationship between the children's dental caries experience, weight status and socio-economic status.

Methods: Cross-over Randomised Controlled Trial with a two-week wash out period. 101 children aged 8-10 years watched a 21-minute cartoon with four 30-second advertisements embedded in the middle. The advertisements were for either cariogenic food and drinks or for toys. A selection of high sugar food and drinks was provided as well as healthy alternatives. Consumption of the pre-weighed, unlabelled food and drink items was calculated in kilocalories and grams of sugar for each child. A dental examination was undertaken for each child. Socio-economic status and Body Mass Index were also calculated.

Results: Children consumed 5.93 grams of sugar ($p=0.014$) and 48.33kcal ($p= 0.008$) more after watching the cartoon with advertisements for cariogenic food and drink items than the advertisements for toys. With regards to sugar intake, children with experience of dental caries had a significantly greater response to the change in advertisements than children with no experience of dental caries. There was no association found between the children's Body Mass Index or Socio-economic status and their response to the change in advertisements. Furthermore, no significant association was found between the children's dental caries experience, weight status and socio-economic status.

Conclusion: The results of this study indicate that a beyond-brand effect exists with respect to both sugar intake and kilocalorie intake in response to cariogenic advertisements. They also indicate that some children may be more susceptible to the advertisements and this susceptibility may contribute to dental caries.

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5 Introduction

Free sugars are described as “all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and fruit juices”[1]. In 2015, the World Health Organisation published guidelines with regards to sugar intake for adults and children[2]. In this document, evidence to support the association between excessive consumption of these free sugars and both dental caries (decay) and childhood obesity was established.

Dental diseases are the most prevalent noncommunicable diseases worldwide[3]. Despite advances in the prevention and treatment of dental caries, it is still a common cause of pain and anxiety amongst children. In addition, it can cause psychological, social and functional distress. Dental caries in industrialised countries has been reported to affect 60-90% of schoolchildren[4]. In 2015, 24.7% of 5-year-old children in the UK had experience of dental caries[5].

Childhood obesity has been described as a modern-day epidemic due to its global nature, growing prevalence and potential for significant immediate and future morbidity and mortality. Conditions such as type 2 Diabetes Mellitus and hypercholesterolemia are becoming more prevalent in youth[6]. In addition, children who are overweight are at a greater risk of being bullied with potential deleterious psychological effects[7]. Furthermore, children who are overweight are at a higher risk of being overweight as adults[6]. It has been estimated that, by 2030, the cost of managing preventable conditions in obese adults will grow by $48-66 billion per year in the US and £1.9-2billion per year in the UK[8].

Although childhood obesity and dental caries are multifactorial in their aetiology, the fact that excessive consumption of sugar is a shared risk factor means that positive effect on both pathologies will result if children’s sugar intake can be reduced. It has been postulated that children’s environment plays a crucial role in their dietary intake[9]. Furthermore, it has been demonstrated that time spent watching television[10] and exposure to television advertising[11] can affect children’s dietary intake.

To investigate the effect that television advertising for unhealthy food and drink items has on children's dietary intake, the children's intake would ideally be measured longitudinally in their home environment while restricting exposure to advertising from alternate media. However, this design would be overly invasive and unethical. As such, previous research has tested children's acute response to television advertisements in a controlled setting[12].

A recent systematic review and meta-analysis demonstrated that acute exposure to food advertising increases food intake in children[12]. Previous trials focus on food intake in terms of weight of food consumed or energy consumed. No evidence exists regarding the potential for high sugar food and drinks advertisements to result in an increase in sugar intake specifically. In addition, as sugar intake is a risk factor for both dental caries and childhood obesity, it is logical to explore the possibility of an association between the effect that advertising may have on a child's dietary intake and their weight status and dental caries status. While there is conflicting evidence with regards to children's weight status and the magnitude of the effect that advertising has[11,13], no evidence exists pertaining to children's caries experience. Furthermore, failure to account for children's socioeconomic status has been suggested as a cause for the conflicting evidence regarding an association between children's weight status and the effect that advertising has on them[14].

As such, the purpose of this study is to investigate if children make different food and drink choices after they have been exposed to advertisements for high sugar (cariogenic) food and drink items compared to non-food or drink advertisements. The secondary aims of this study are to investigate if caries status, weight status and socioeconomic status are associated with differences in children's response to the food advertising. Furthermore, to investigate the association between caries experience, weight status and socioeconomic status.

The results of this study will provide novel and valuable evidence regarding the role that television advertising for cariogenic food and drink items has on children's sugar intake. This may help inform regulations that could create a less cariogenic and obesogenic environment for children. As such, this research has the potential to make a positive impact on children's health.

5.1 Aims of study

5.1.1 Aims

- The primary aim of this study was to investigate if 8-10-year-old children consume more sugar and/or kilocalories after they have been exposed to a cartoon embedded with advertisements for high sugar (cariogenic) food and drink items compared with the same cartoon with non-food and drink advertisements.

The secondary aims of this study were:

- To investigate the relationship between the children's response to the change of advertising content and their caries experience, weight status and socioeconomic status.
- To assess the relationship between the children's caries status, weight status and socioeconomic status.

6 Literature Review:

6.1 Overweight and Obesity in Children

6.1.1 Definition

Obesity has been defined as an “abnormal or excessive fat accumulation that may impair health”[15]. It is described as a chronic disease, which is long-term or lifelong for most individuals[16]. Obesity is prevalent in developed and developing countries and affects both adults and children[17]. Overweight refers to a “pre-obese” weight status and is often described in conjunction with or combined with obesity in epidemiological studies[17].

6.1.2 Measurement and Classification

To facilitate individual and population assessment, it is necessary to measure body fat and categorise weight status[17]. The measurement of body fat can be done using various methods which assess different characteristics of obesity (see table 1)[17]. However, the use of many of these methods is precluded for public health and research purposes by cost and/or practicality.

Characteristic of obesity measured	Measurement tool
Body composition	Body Mass Index (BMI), waist circumference, underwater weighing, dual energy X-ray absorptiometry (DEXA), isotope dilution, bioelectrical impedance, skinfold thickness
Anatomical distribution of fat	Waist circumference, weight-height ratio, computer tomography, ultrasound, magnetic resonance imaging.
Partitioning of nutrient storage	^{13}C Palmitic acid test, extended overfeeding challenge
Energy intake	Dietary record/recall
Energy expenditure	Calorimetry, physical activity level assessment, motion detector, heart rate monitor

Table 1: Methods of Measuring body fat[17]

Of the various methods, the anthropometric methods are the most frequently used, especially Body Mass Index (BMI). BMI is simple ratio of an individual's weight to their height squared. The ratio accounts for taller people having more tissue than shorter people and thus tending to weigh more[18]. Although it is often considered an indicator of body fatness, it is a surrogate measure of body fat as it measures excess weight rather than fat per se[19]. As such, it does not discriminate between fat and non-fat mass such as bone or muscle. Furthermore, most research regarding the use of BMI has used white populations, as such some caution has been raised regarding its use in non-white populations[20].

Despite this, the fact that BMI is a simple, inexpensive and non-invasive method has seen it described as "the best available tool for monitoring progress in the campaign against obesity"[21]. In addition, BMI has been shown to correlate with more direct measures of body fat including underwater weighing and dual energy X-ray absorptiometry[22].

Using BMI, the adult cut off points for overweight and obesity are 25 kg/m² and 30 kg/m² respectively[17]. Although these figures are relatively arbitrary round numbers, they are reported to be related to health risk[17]. The cut-off points indicate that health risks are greatly increased above these values but not that a BMI below this level indicates that the individual is free from such risks.

In children, especially those under 10 years of age, BMI has been found to be positively correlated to measurements of body fat using total body electrical conductivity[23]. However, a concern with the use of BMI in children is that it does not account for gender related differences nor the changes in body composition that occur with age[22]. Cole *et al*[24] illustrates this point by pointing out that at birth, median BMI is 13 kg/m² , by the age of 1 median BMI increases to 17 kg/m² , it then decreases to 15.5 kg/m² by 6 years of age and increases again to 21 kg/m² by the age of 20. Consequently, in 1999, a workshop organised by the International Obesity Task Force recommended that adult cut off points be linked to body mass index centiles for children to provide appropriate child cut off points[25]. As such an age-specific table of cut off BMI values has been developed (see table 2)[24]. The table provides cut off values for classification as overweight or obese, for both males and females at 6-month increments from 2 years of age to 18 years of age.

Age (Yrs)	Overweight		Obese	
	Male	Female	Male	Female
2	18.4	18.0	20.1	20.1
2.5	18.1	17.8	19.8	19.5
3	17.9	17.6	19.6	19.4
3.5	17.7	17.4	19.4	19.2
4	17.6	17.3	19.3	19.1
4.5	17.5	17.2	19.3	19.1
5	17.4	17.1	19.3	19.2
5.5	17.5	17.2	19.5	19.3
6	17.6	17.3	19.8	19.7
6.5	17.7	17.5	20.2	20.1
7	17.9	17.8	20.6	20.5
7.5	18.2	18.0	21.1	21.0
8	18.4	18.3	21.6	21.6
8.5	18.8	18.7	22.2	22.2
9	19.1	19.1	22.8	22.8
9.5	19.5	19.5	23.4	23.5
10	19.8	19.9	24.0	24.1
10.5	20.2	20.3	24.6	24.8
11	20.6	20.7	25.1	25.4
11.5	20.9	21.2	25.6	26.1
12	21.2	21.7	26.0	26.7
12.5	21.6	22.1	26.4	27.2
13	21.9	22.6	26.8	27.8
13.5	22.3	23.0	27.2	28.2
14	22.6	23.3	27.6	28.6
14.5	23.0	23.7	28.0	28.9
15	23.3	23.9	28.3	29.1
15.5	23.6	24.2	28.6	29.3
16	23.9	24.4	28.9	29.4
16.5	24.2	24.5	29.1	29.6
17	24.5	24.7	29.4	29.7
17.5	24.7	24.8	29.7	29.8
18	25.0	25.0	30.0	30.0

Table 2: International cut off points for body mass index for overweight and obesity by sex between 2 and 18 years. (Cole et al, 2000[24]*)*

A further development of the BMI is the BMI z-score, also called the BMI standard deviation score. It is a measure of relative weight adjusted for child age and sex[26]. BMI z-score allows a practitioner to use a simple online tool[27] to enter patient weight, height, gender and age. The tool will then calculate a BMI z-score and percentile, allowing the clinician to establish whether the child is in the “at risk of overweight” category 85th-95th percentile or “overweight category” >95th percentile.

6.1.3 Aetiology

Obesity can be described as primary or secondary. The aetiology of primary obesity is a chronic energy imbalance due to excess energy intake and/or insufficient energy expenditure. Secondary obesity is secondary to another health condition, such as endocrine or genetic abnormalities[28].

With regards to energy intake, it is not just the quantity of food and drink that is important but also the specific composition of the diet. Children's diets that are high in saturated fat, added sugars, and sodium are associated with increased obesity and other negative health consequences[29–31]. In the US, approximately 40% of children's total energy intake comes in the form of empty calories, or low-nutrition food and drink, with 20% from solid fat and 18% from added sugars[32].

In terms of energy expenditure, the increased use of cars and the associated reduction in walking and cycling has seen a fall in energy expenditure amongst children[33]. In addition, more passive technology based pursuits are growing in popularity[34]. Although the strength of evidence for a direct association between physical activity levels and obesity is weak[35], there is a strong link between the lifestyle associated with inactivity and levels of obesity[36].

As obesity results from an energy imbalance, the quantification of this relationship is of practical interest. Historically, the National Health Service (NHS) in the UK and the National Institute of Health (NIH) in the US have erroneously stated that a steady weight loss of 0.5kg per week will occur with a reduction in energy of 2 Megajoules/477.7kilocalories per day[37]. Hall *et al* have since highlighted the fact that as weight loss or gain occurs, energy requirements reduce and increase and as such a constant relationship between kilocalorie intake and weight loss/gain will not occur[37].

In children, it has been reported that a sustained daily overconsumption of as little as 46kcal per day may lead to them becoming overweight/obese[38]. Thus, a relatively small energy imbalance sustained over a long period can have a significant cumulative effect.

Many models have been devised which attempt to describe the multi-factorial aetiology of childhood obesity. One such model is the “ecological model”. Egger and Swinburn propose three main influences on body fat equilibrium: biological, behavioural and environmental (see figure 1)[9]. Moderators are those behavioural changes which may follow a disequilibrium in energy balance. For instance, if a net negative balance exists, appetite may increase and/or physical activity may decrease- thus moderating the effect of the negative energy balance on body weight.

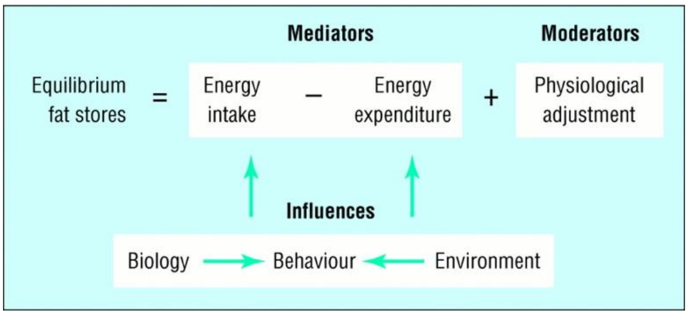

Figure 1: Aetiology of childhood obesity: The Ecological Model[9]

In this model, biology refers to those biological factors which are known to affect body fat levels. For instance, age, gender, hormonal factors and genetics[28]. Behaviour refers to the propensity for an individual to act in a way which will promote obesity. It is described by Egger and Swinburn as the predilection towards “sloth” and “gluttony”. Finally, Environment is divided into macro and micro factors. Macro factors are those environmental conditions which affect the wider population, for example public health policy and the actions of the food industry. Micro factors are those environmental factors which are more local to the individual, for example proximity to a gym and neighbourhood accessibility to fresh produce.

As such, models such as Egger and Swinburn's serve to highlight the fact that childhood obesity depends on more than individual genetics and actions. It also depends on factors outside of the individual i.e. the child's social, cultural and physical environment[28]. Micro-environmental factors include family, school and neighbourhood environmental influences- all of which have been shown to play a crucial role in establishing behaviours which may prevent or promote obesity[39–41]. Macro-environmental factors include industry, media and government.

The food industry is responsible for the nature, price and availability of products[28]. As such, it plays a crucial role in facilitating childhood obesity. The media also play a key role in the promotion of health and unhealthy behaviour. Although there are examples of the media promoting healthy food options[42], the vast majority of research focuses on the negative effect that advertising for unhealthy food has on children's dietary preferences and intake, this is discussed in detail in section 6.4.

Finally, the government has the overarching power to both restrict and regulate industry and the media. It is the responsibility of governments worldwide to act on the childhood obesity epidemic. Indeed, the UN's "Convention on the Rights of the Child" state that governments must "provide good quality health care, clean water, nutritious food, and a clean environment and education on health and well-being so that children can stay healthy"[43]. Apart from the clear ethical obligation due to raised morbidity and mortality rates, the economic burden associated with the cost of treating obesity related illnesses is substantial and growing. Relatively recent estimates suggest that obesity costs the NHS approximately £7 billion per year[44]. By 2030, it has been predicted that there will be 65 million more obese adults in the US and 11 million more obese adults in the UK[8]. As such, the cost of treating obesity related preventable diseases is set to soar. In the US, it has been estimated that by 2030, the combined medical costs of treating obesity related preventable diseases will have increased by $48-66 billion per year and £1.9-2 billion per year in the UK[8].

6.1.4 Prevalence

The prevalence of overweight and obese children is increasing worldwide[45]. Between 1980 and 2013, the prevalence of overweight and obese children rose by 47.1%[46]. Geographical variation has been reported with particularly high rates of overweight and obese children in the Middle East and the Pacific Islands[46]. Prevalence rates are higher in developed countries than in developing countries[46]. However, in absolute numbers, there are more overweight and obese children living in low and middle-income countries than in high-income countries[46].

In Europe, prevalence rates vary considerably by country. In 2013, in Greece, 33.7% of boys were overweight and 10.5% obese while 29.1% of girls were overweight and 7.9% obese. These figures were much lower in the Netherlands with 18.3% of boys being overweight and 4.1% obese while 16.1% of girls were overweight and 3.8% obese. In the UK, in 2013, 26.1% of boys were categorised as overweight with 7.4% obese while 29.2% of girls were overweight and 8.1% obese[46].

In England, the Child Measurement Programme[41] provides greater insight into the epidemiology of childhood obesity at a national level. Height and weight measurements are taken of children in reception (aged 4-5 years) and in year 6 (aged 10-11 years). The 2015/16 report demonstrates variations in obesity levels, with London, the North East and the West Midlands having particularly high levels of obesity at both reception and year 6. The prevalence of obesity in the North West of England is reported to be 9.8% for reception and 20.6% for year 6[41].

Nationally, the prevalence of obesity was higher amongst boys than girls. Ethnicity also accounted for variation with Black or Black British children having higher rates of obesity in both age groups. A growing deprivation gap was reported with deprived areas having higher levels of obesity. In London, although less than 30 miles separate Richmond and Barking the socioeconomic divide is evident with 11% of year 6 students in Richmond being categorised as obese compared to 28.5% in Barking[41]

6.1.5 Obesity and Socioeconomic Status

The prevalence of childhood obesity is greater in more deprived areas of the UK[41]. This relationship has been confirmed by using father's occupation as an indicator for socioeconomic status[47] and by using a combination of head of household occupation, education level and employment status[48].

The reason for this relationship is complex and uncertain. It may be that socioeconomic status is acting as a proxy for the effect of multiple adverse childhood events[28]. It may also be due to a higher density of fast-food outlets[49] in lower socioeconomic communities or a lack of access to fresh nutritious produce and an abundance of energy-dense low-nutrition produce[50]. Alternatively, it may be due a lack of funds or access to safe play areas resulting in lower energy expenditure[28].

However, it should be noted that not all studies support this relationship between lower socioeconomic status and childhood obesity[51]. It appears that, depending on the indicator of socioeconomic status used, different findings can result. There is also evidence from Asia that affluence may be associated with childhood obesity[52]. However, this relationship may be due to the cultural preference for fatness or thinness rather than being a direct effect of affluence as such[28].

6.1.6 Treatment and Prevention

As obesity is the result of an imbalance between energy intake and expenditure, alteration of either can help to prevent or treat obesity. With regards energy intake, this can be achieved by altering the quantity and nature of food consumed. An inverse relationship between fruit and vegetable intake and childhood obesity has been demonstrated[53]. In addition, an inverse relationship between dietary calcium intake and obesity has also been demonstrated[54]. Furthermore dietary fibre has been shown to induce satiety and so it is reasonable to assume that diets rich in whole grains, legumes, nuts, fruits and non-starchy vegetables will aid in the prevention and treatment of childhood obesity[55]. Conversely, the consumption of unhealthy foods such as sweetened beverages[56], has been shown to be positively associated with childhood obesity.

In addition to altering the quantity and nature of food being consumed, food behaviours such as skipping breakfast[57], snacking[58] and eating out[59] have been reported to be associated with childhood obesity.

With regards to energy expenditure, the CDC recommend that children aged 6-17 should have sixty or more minutes per day of aerobic activity, with most of the activity being moderate or vigorous intensity. In addition, they should have vigorous exercise on at least three days per week[60]

However, tackling the global epidemic of childhood obesity is far more complex. While an imbalance between energy intake and expenditure is undoubtedly the cause, the evidence shows that it is increased energy intake which is driving global childhood obesity[61].

The World Health Organisation have developed a series of recommendations to address childhood obesity[62]. In it they set out six key areas to focus on:

- Promote intake of healthy foods
- Promote physical activity
- Preconception and pregnancy care
- Early childhood diet and physical activity
- Health, nutrition and physical activity for school age children
- Weight management.

In August 2016, the UK Government published its plan for action regarding childhood obesity[63]. In this document, the government acknowledge the scale and complexity of the challenge. The aim of the plan is to significantly reduce England's rate of childhood obesity within the next ten years. The plan contains fourteen initiatives. (See table 3)

Introducing soft drinks industry levy	Improving the co-ordination of quality sport and physical activity programmes for schools
Taking out 20% of sugar in products	Creating a new healthy rating scheme for primary schools
Supporting innovation to help businesses to make their products healthier	Making school food healthier
Developing a new framework by updating the nutrient profile model	Clearer food labelling
Making healthy options available in the public sector	Supporting early years setting
Continuing to provide support with the cost of healthy food for those who need it most	Harnessing the best new technologies
Helping all children to enjoy an hour of physical activity every day	Enabling health professionals to support families

Table 3: Initiatives to reduce childhood obesity in the UK

An omission from the 2016 plan for action is the regulation of advertising of unhealthy food and drink items to children. In November 2015, the House of Commons Health Committee published a report entitled "Childhood Obesity- brave and bold action[64]. Alongside many of the recommendations seen in the 2016 plan for action, the 2015 report also recommends "Tougher controls on marketing and advertising of unhealthy food and drink".

6.2 Childhood Dental Caries

6.2.1 Definition

Dental caries, commonly referred to as tooth decay, is the localised destruction of dental hard tissues by acidic by-products of bacterial fermentation of dietary carbohydrates[65]. Dental caries is the most common chronic infectious disease of childhood[66]

Similar to obesity, the prevalence of dental caries amongst children has been cited as a major public health challenge facing this and future generations[4]. Dental caries can lead to pain and/or infection[67]. It can affect both the immediate and long-term quality of life of children and their families[68]. In addition, the consequences of dental caries can have significant social and economic effects beyond the individual/family[68,69].

The treatment of dental diseases is expensive, consuming 5–10% of health-care budgets in industrialised countries[67]. In the UK, in 2013-14, 46,500 children and young people were admitted to hospital for a primary diagnosis of dental caries. Furthermore, in 2012-13, £30 million was spent on hospital based extractions for children alone[67]. In addition, children who experience early childhood tooth decay have an increased risk of further caries in both their primary and permanent teeth[66].

6.2.2 Aetiology

The classic model of dental caries formation has four essential elements: A tooth surface (substrate), acid producing bacteria, fermentable carbohydrates and time[70].

The tooth surfaces most commonly involved are enamel and dentine. Enamel is the highly mineralised outer shell of teeth. It is primarily composed of inorganic crystalline calcium phosphate (96%) with a small proportion of organic material and water[71]. Dentine lies beneath enamel and surrounds the vital tissue within the dental pulp. Dentine is composed of crystalline calcium phosphate (45%), organic material (33%) and water (22%)[71]. Less commonly, dental caries affects the covering of dental root surfaces termed cementum.

The second requirement for dental caries formation is acid-producing bacteria. Bacteria adhere and aggregate on tooth surfaces. The bacteria then become embedded within an extracellular matrix of proteins and polysaccharides, produced by the bacteria themselves, to form a biofilm[72]. This biofilm of bacteria is commonly referred to as dental plaque. Dental plaque contains a diverse ecosystem of bacteria. Within this eco-system are bacteria which produce acids as a by-product of their metabolism of fermentable carbohydrates. Historically, *Streptococcus mutans* has been most strongly associated with dental caries[73]. However, in recent years, it has become evident that many other bacterial species can be implicated including *Veillonella, Streptococcus sobrinus* and *Lactobacillis*. It has been suggested that multiple microorganisms act collectively and perhaps synergistically in the initiation and progression of dental caries[74].

The third requirement for dental caries formation is fermentable carbohydrates. Fermentable carbohydrates are sugars that are easily broken down by bacteria. They include monosaccharides, disaccharides, oligosaccharides and polyols. However, it is primarily the low molecular weight monosaccharides and disaccharides which are associated with dental caries formation. The acidogenic bacteria metabolise the sugar and produce acidic by-products including lactic acid. These acids then promote the dissolution of the crystalline calcium phosphate of the tooth structure resulting in dental caries. Sucrose, glucose, fructose, maltose and lactose are all examples of mono and disaccharides capable of causing dental caries. Although these sugars are often naturally present, food and drink manufacturers frequently add them to products to improve flavour. In addition, sugars are often added for bulking, browning, texture and preservation reasons. Sucrose is the most commonly added sugar due to its intense sweetening effect[75]. At population levels, a strong positive linear correlation (r= +0.77) has been demonstrated between the frequency of sucrose intake and dental caries levels[76].

The final requirement for dental caries formation is time. Although the demineralisation of dental tooth structure occurs regularly, dental caries is not inevitable. Instead a balance between dental demineralisation and remineralisation exists. Following exposure to a glucose rinse it has been demonstrated that the plaque pH drops. At pH levels below 5.5 net demineralisation of dental hard tissues occurs. The pH returns to normal levels after 30 minutes to 1 hour. This is graphically demonstrated by the Stephan curve[77] (see figure 2). As such, frequent sugar exposure over a prolonged period, results in net demineralisation and dental caries. An increase in caries levels has been demonstrated in children who consume sugar more than four times per day in total and with more than 3 sugary snacks between meals[78].

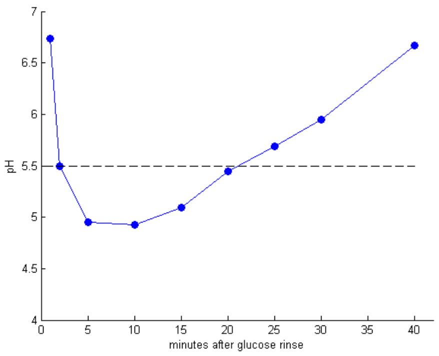

Figure 2: The Stephan curve: Demonstrating the effect that exposure to glucose has on plaque pH [79].

6.2.3 Prevalence

Dental caries in industrialised countries has been reported to affect 60-90% of schoolchildren and the vast majority of adults[4]. Despite these high levels, a decline in caries prevalence has been reported over the past 20 years amongst children in Western countries[80]. In England, between 2008 and 2015 a 20% decrease in the proportion of 5-year old children with experience of tooth decay has been reported[5]. In developing countries, increased consumption of sugar and inadequate preventative measures has seen a steady increase in previously low levels of dental caries[4].

In 2011-2012, 23% of children in the United States aged 2-5 years had experience of dental caries[81]. In 2015, 24.7% of 5 year-old English children had experience of dental caries[5]. Nationally, the average number of decayed, missing or filled teeth was 0.8 per child. Amongst children with caries experience, the average number of decayed, missing or filled teeth was 3.4[5]. In addition, variations in caries experience was noted amongst children of different ethnic backgrounds with the highest rate among Chinese children (24.8%) and the lowest among white children (3.9%).

6.2.4 Assessment and Indices

Assessment for and quantification of dental caries for an individual is a relatively straightforward process which involves undertaking a dental history assessment, a clinical examination and investigations such as dental x-rays. However, with population studies, taking a dental history and radiological investigations are neither practical nor ethical. Thus, indices have been developed which allow dental caries prevalence and/or dental treatment need to be assessed through a simplified clinical examination. Examples of such indices include:

- Decayed, Missing and Filled Teeth (DMFT/dmft)
- Decayed Missing and Filled Surfaces (DMFS/dmfs)

- Stone’s Index
- Caries Severity Index
- Caries susceptibility Index
- Functional Measure Index
- Caries Index
- Tissue Health Index
- Dental Health Index
- Moller’s Index
- Restorative Index.

The DMFT Index is reported to be the most commonly used epidemiological index for assessing dental caries[82]. The Index has been in use for over 75 years[82] and involves recording a tooth as either unaffected or decayed, missing or filled. If the tooth is unaffected a score of 0 is allocated. If a tooth is either decayed, missing or filled it is allocated a score of 1, meaning that caries is assumed to have affected that tooth. No tooth can score more than 1 even if it has both decay and a filling present[83]. The DMFT index can be used for both deciduous (primary) teeth and permanent teeth.

The DMFT Index has limitations however. Firstly, it has been pointed out that all missing teeth are assumed to have experienced caries, this may not be the case[84]. Teeth may have been extracted due to malformation[85] or for orthodontic reasons[86]. In addition, it has been reported that there is a 44% chance that the DMFT value recorded will be lower than the true value due to a lack of radiographical investigation[87]. In addition, the “Filled” component may be inaccurate as an indicator of previous caries experience as clinicians differ in management of staining in the fissures (grooves) of teeth and some of the modern dental materials may be virtually indistinguishable to the naked eye[88]. Finally, there is the issue of how to handle the mixed dentition phase. During this developmental phase, the loss of teeth may be due to the natural eruption of permanent teeth or due to caries. Making a judgment as to the cause of tooth loss leaves the index open to conjecture. Some authors have suggested omission of the “Missing” component during the mixed dentition and the use of an alternative DFT index[89].

Despite its limitations, the DMFT index remains the most widely utilised index and is used nationally and internationally to investigate variations in caries prevalence[4,5].

6.2.5 Prevention

Strategies to prevent dental caries usually focus on the following areas[65]:

- Reducing the amount and frequency of free sugar intake,
- Oral hygiene promotion: to promote the removal of acidogenic bacteria with regular brushing and interproximal cleaning,
- The use of topical applications such as fluoridated toothpastes, varnishes, gels and mouth rinses: to increase the resistance of teeth to caries,
- Promotion of professional dental care to educate, prevent and treat caries.

Free sugars are defined by the WHO as “all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups and fruit juices”[2]. The World Health Organisation has strongly recommended that both adults and children reduce the intake of free sugars to less than 10% of total energy intake[2]. This equates to approximately 50g of free sugars for a person of healthy body weight[90].

6.2.6 Childhood Caries and Childhood Obesity

A positive correlation between childhood obesity and caries may appear obvious due to the multitude of shared risk factors[50]. However, there is conflicting evidence both for an association[91] and against it[92]. In addition, and rather interestingly, an inverse relationship has also been reported[93]. The fact that most studies focus on a particular geographical location means that confounding factors such as water fluoridation or public health policies may influence outcomes.

The strongest evidence that an association exists comes from a recent systematic review and meta-analysis which found a statistically significant relationship between dental caries and childhood obesity (effect size = 0.104, P= 0.049)[94]. This relationship was particularly strong in the permanent dentition and in industrialised countries.

6.2.7 Childhood Caries and Socioeconomic Status

Where people live may influence their risk of developing tooth decay[50]. A higher prevalence of caries is reported amongst people with poor education and/or low socioeconomic status. This may be due to parental dietary habits[95] or parenting methods[96] such as the use of food to satisfy their children's emotional needs[96]. In addition, the nature of easily accessible foods may vary by neighbourhood. Convenience stores offering high-energy, low-nutrient-dense foods may predominate in one region as opposed to supermarkets with a wide variety of fruits, vegetables and other healthy foods[50].

In England, regional disparity exists with the highest rate of caries amongst 5-year-olds in the North West. The North West also has some of the highest levels of social deprivation in the country[97]. Levels of decay have been shown to be positively correlated with social deprivation as measured by the index of multiple deprivation (IMD), this has been a repeat finding across the 2008, 2012 and 2015 National Dental Epidemiology Programme for England reports[5].

6.3 Television watching: Effects on Obesity, Dietary Intake and Dental Caries

6.3.1 Television watching and obesity

Due to the sedentary nature and propensity for snacking on unhealthy food and drinks[98] while watching television, an association between time spent watching television and childhood obesity has been suggested[28].

Furthermore, it has been claimed that more than 60% of overweight incidence of children and adolescents in the US can be attributed to television. In addition, the adjusted odds of incidence for being overweight were 8.3 times greater for those watching more than 5 hours of television per day compared with those watching for less than 2 hours[99].

A study of 2223 adolescents, investigated an association between BMI and hours spent watching television per day. The authors found that for each additional hour of television watching the BMI increased by 0.9. Adolescents who watched more than 2 hours of television per day were also twice as likely to be overweight than those who watched less than 2 hours[100]. Another study investigating an association between child weight status and television viewing reported that children's television viewing was associated with BMI. This association was attributed to displacement of physical activity and/or increased energy intake during viewing[101].

The notion that displacement of physical activity is the drive behind television being associated with higher BMI scores is debated. It has been demonstrated that the effect size of time spent watching television is larger than those commonly reported for nutritional intake and physical activity[102]. In addition, the effect remains significant even when parental BMI and socioeconomic status are accounted for[102].

The concept of dishabituation of eating patterns has also been proposed as a possible method by which increased television viewing is associated with higher BMI values[98]. Finally, and of relevance to the current study, it has been demonstrated that exposure to unhealthy food and drink advertisements while watching television may drive unhealthy dietary intake[103].

6.3.2 Television watching and dietary intake

Watching television is often claimed to result in increased energy intake as well as reducing energy output[104]. Attempts to quantify the effect of television watching on energy intake have been made. In one study , it is claimed that watching 5 or more hours of television per day resulted in an extra 175 kcal energy intake compared with those watching 1 hour or less[10]. A further study found that an additional 167 kcal was consumed per extra hour of television watched per day[105]. Over a sustained period, in the absence of a concurrent and equivalent increase in energy expenditure, this increased consumption would inevitably amount to weight gain.

The mechanism by which television affects weight is thought to be by altering dietary intake patterns[98]. This is predominantly associated with increased consumption of unhealthy, energy-dense-nutrient-poor foods[106]. However, television watching is also reported to be associated with reduced consumption of healthy foods such as fruit and vegetables[107]. Furthermore, it has been claimed that a significant proportion of children’s daily energy intake is consumed while watching television, 17-18% on weekdays and 26% at weekends[36]. Accordingly, a significant portion of children’s daily dietary intake is directly subjected to the effect that television and/or unhealthy food and beverage advertising may have.

6.3.3 Television watching and dental caries

While there is an abundance of evidence demonstrating an association between both television watching and advertisements and obesity, there is less evidence with regards an association with dental caries. However, it would seem plausible that a similar trend would be found due to the shared risk factors between obesity and caries.

A 2014 study investigated an association between duration of television watching and dental caries experience[108]. The authors found a higher probability of having more decayed teeth with increasing time spent watching television. A steady rise in the rate ratio was noted in DMFT as television viewing time increased.

6.4 Television Advertising and Children

6.4.1 Definition

Advertising has been defined by the Advertising Association of the UK as[109]:

> *"a means of communication with the users of a product or service. Advertisements are messages paid for by those who send them and are intended to inform or influence people who receive them"*

According to the Advertising Association, in 2011, UK businesses spent £16 billion on advertising[110]. It has been estimated that for every pound spent on advertising six pounds is added to the UK GDP, meaning a £100 billion contribution to GDP annually[110]. Advertising is also cited as promoting innovation and differentiation of products. It encourages market growth and drives price competition[110].

6.4.2 Television Advertising

With the emergence of new media devices and the increasing time spent online, there has been a decrease in the amount of time children spend watching television per week[111]. In 2016, in the UK, 5-15 year old children were watching 13 hours 36 minutes per week compared with 14 hours 48 minutes in 2015[111]. Despite the reduction in viewing time, television remains the only media format that a majority (80%) of children in the UK use almost every day[111]. It is also cited as the one device they would miss the most if taken away[111]. Watching television is viewed as an important family activity and this is reflected by the largest number of children watching television during family viewing hours (6pm-9pm)[111]

In the US, it has been reported that companies spend at least $1.6 billion annually on food advertising directed to children and adolescents[112]. Furthermore, it is estimated that children watch approximately 20,000 television advertisements every year[113]. In the UK this figure is slightly lower at 18,000, however this is still higher than their European counterparts[114].

6.4.3 Content of Television Advertising

Given the extent of children's exposure to television advertising many studies have been published investigating the content of advertisements. In the UK, in 2008, food and drink items were the third most commonly advertised products[115]. In addition, there were significantly more food and beverage adverts during peak children's viewing hours than non-peak children's viewing hours[115]. Significantly more non-core food and beverage adverts were shown on children's channels compared with family channels[115].

Comparing the content of television advertising over a one week period in the UK with Canada, Adams et al reported that food adverts of particular appeal to children amounted to 6.6% in the Canadian sample compared with 10.5% in the UK sample[116].

With regards to cariogenic food and beverage advertisements in the UK, it was reported that in 2006, 6.3% of all advertising time was devoted to potentially cariogenic products. Sugar sweetened cereals being the most commonly advertised products followed by sweetened dairy products and confectionary[117]. Similarly, a large-scale study by Al-Mazyad *et al* investigated the content of UK television advertisements in relation to dental health in 2016. They found that food and beverages were the second most commonly advertised product. In addition, almost two-thirds of the food and beverage products advertised were potentially harmful to teeth[118].

In the US, a 2016 study by Vilaro *et al*, assessed the content of 32 hours of children's television from February 2013. The authors report that 13.75% of advertisements promoted a food or beverage product. Of these, 54.6% were promoting an unhealthy product and 95.48% used persuasive tactics to do so. In addition, food adverts aimed at children used significantly more persuasive tactics than those aimed at adults[119].

In Spain, in 2016, adverts on five channels over a one-week period were assessed for content. 23.7% of adverts on television were from the food industry. In addition, 64% of these were for high fat, salt, or free sugar (HFSS) products. Despite a non-statutory code of practice, 67.8% of adverts on channels of particular appeal to children were for HFSS products and 70.7% were on broadcasts specifically regulated by the Spanish Code of self-regulation[120].

6.4.4 Response of Children to Television Advertising

Television advertising has been described as a "pervasive presence" in the lives of children[113]. Indeed, regarding media usage, too many television adverts is reported as one of the most common dislikes for 8-15 year olds in the UK[111]. With the level of exposure of children to advertising, concern has been raised about children's ability to comprehend the motive and messages contained in television adverts[121]. Despite contentions to the contrary[114], there is evidence that advertisements can persuade children and make products desireable[122].

Advertisements make a strong impression on children[121]. Most children are able to recognise and recall the content of adverts after only a brief exposure[121]. Children as young as 6 years old exhibit some memory of advertisements. However, at this age they fail to understand the purpose of advertising. By the age of 8, 25% of children understand the persuasive intent of advertising and by 10 years of age 36%[121]. As such, many children will perceive information contained in adverts as facts and concern exists regarding the potential of adverts to foster unrealistic expectations[113].

Credence of television advertising has been shown to reduce with age with boys being more likely to believe advertising content than girls[123]. In addition, children who own more brand name products are reported to be more heavily influenced by advertisements[123].

Finally, a significant association has been reported on a global scale between the number of television advertisements for sweet or fatty foods and national levels of overweight[124].

6.4.5 Influence of Socioeconomic Status

Socioeconomic status has been shown to be a predictor of children's enjoyment of television advertisements[123], with children from a higher socioeconomic background enjoying advertisements less[123]. This variation in susceptibility to advertising may be due to parental involvement, parental attitudes towards advertising, family communication and parenting styles[125]. In addition, it has been shown that coming from a higher socioeconomic status family can lead to a more realistic perception of advertisements, reducing the desirability and request for the products being advertised[123].

6.4.6 Regulation of Television Advertising

In Sweden, a ban has been placed on all television advertising to children[126]. This is due to policymakers belief that children under 12 are unable to understand the purpose of advertising[127]. Similarly, Norway and the province of Quebec in Canada have adopted this blanket ban of advertising any product to children[128].

In the US, in 2006, the Institute of Medicine published a report stating that there is strong evidence that marketing of foods and beverages to children influences their preferences, requests, purchases, and diets[129]. A Joint Task Force on Media and Childhood Obesity was also established in 2006 to examine the impact of media on childhood obesity and to develop voluntary industry standards to limit advertising that targets children[130]. That same year, many large companies joined the Children's Food and Beverages Initiative (CFBAI) which was intended to tip the balance in favour of advertising healthy eating and lifestyles[131]. A commitment was made not to advertise during programming with 50% of the audience aged under 12. The Federal Trade Commission (FTC) has established voluntary principles but questions have been raised regarding the effectiveness of this approach[132].

In 2009, the Australian Food and Grocery Council introduced its Responsible Child Marketing Initiative[133]. This voluntary initiative limited advertising of products to children under 12 to those which promote healthy dietary choices and lifestyles. Further voluntary initiatives such as the Quick Service Restaurant Initiative limiting fast food advertising were also introduced. However, there was limited government regulation of children's programs and in 2017 an investigation into the content of advertisements on Australian television found that there had been no significant changes in unhealthy food advertising. The author surmises that self-regulation is inadequate and that government enforced standards are required[133].

In 2010, the WHO published recommendations on the marketing of foods and non-alcoholic beverages to children[134]. The report highlighted the need to restrict advertisements for unhealthy food and drink items to reduce childhood obesity.

In Canada, self-regulation codes of practice of advertising to children are in place and have been strengthened in response to concerns regarding the vulnerability of children to the effects of advertising[116].

In South Korea, in 2010, restrictions were placed on the advertisement of Energy-Dense-Nutrient-Poor foods targeting children. The restrictions were placed on advertisements before during and after programs broadcast from 5pm-7pm. Threshold levels for energy, salt, sugar, fat and minimum levels of protein were set by the Korean Food and Drug Administration. The aim was to change children's eating behaviour by reducing their exposure to unhealthy advertisements. While there were encouraging outcomes, it was found that some food companies bypassed the regulations by altering their serving sizes[135].

In the UK, in 2007, scheduling restrictions were put in place with the aim of reducing children's exposure to high fat, salt and sugar (HFSS) adverts[136]. The scheduling restrictions, prohibit advertisements for HFSS food and drinks on all children's channels and on non-children's channels during or around programmes 'of particular appeal to' 4–15 year olds[136]. However, despite good adherence to these regulations, it has been reported that the restrictions did not achieve their aim and that children's exposure to "less healthy" food adverts has remained unchanged[137]. These findings are attributed to the fact that children watch a wide range of television, beyond programmes specifically targeting children. It has been suggested that future interventions should use a time-based watershed as opposed to programme content based restrictions or the percentage of viewers that are children [137].

A 2013 paper by Galbraith-Emami and Lobstein reviewed the impact of initiatives to limit advertising of unhealthy food and beverages to children[128]. The authors commend companies for joining voluntary initiatives, however, they stress that these initiatives have not and are unlikely to have the desired effect. Instead, the authors recommend comprehensive, statutory measures with adequate monitoring and sanctions for non-compliance[128].

6.4.7 Television advertisements and dental caries

An association between watching television advertisements and caries experience has been reported[138]. In this questionnaire and dental examination based study, children that reported that they watched advertisements when they came on during television programmes (as opposed to not watching them) had a higher DMFT on average. In addition, children who reported asking their parents to buy advertised food and soft drink items had a higher DMFT.

6.4.8 Television advertisements and dietary intake

While television viewing has been shown to be associated with obesity by many authors, Zimmerman and Bell have demonstrated that television viewing does not lead to obesity due to it being sedentary in nature. Instead, the relationship is due to the associated exposure to unhealthy food and beverage advertising[103]. This contention is supported by the fact that exposure of children to television programming with advertisements for food products embedded resulted in a preference for the advertised food[139].

In 2015, Kelly *et al*, published a literary review based on the effects that unhealthy food promotion has on children's behaviour[140]. A hierarchical model is presented demonstrating that advertising initially serves to raise awareness. Continued exposure leads to the development of preferences and purchase intent. This then results in purchase of the product, consumption and finally results in post-consumption effects such as weight gain or dental caries development.

This association between exposure to television advertisements for unhealthy food and beverage advertisements and alterations in dietary intake has led to several randomised controlled trials investigating the acute effect that exposure to advertising has on children's dietary choices.

6.4.9 Randomised Controlled Trials investigating the effect of advertising on children's dietary choices

In 2016, a systematic review and meta-analysis was published based on studies that have manipulated acute exposure to unhealthy food advertising and measured subsequent food intake[12]. The review included 22 articles based on adults and children of which 18 could be included in meta-analysis. Due to heterogeneity of the outcome measures, the authors converted the individual outcomes to a standardised mean difference (SMD), this allowed for meta-analysis. It was found that exposure to food advertising resulted in greater food intake when compared to exposure to control advertisements. Overall, this effect was small-to-moderate in size. When studies looking at adults only were included- no evidence of an effect was noted. However, when children were looked at in isolation, the effect was of moderate size. Thus, the authors conclude that exposure to food advertising increases food intake in children but not adults.

On further exploration, twelve studies were included in the meta-analysis which looked at the effect of advertisements on children. From these twelve studies, thirteen comparisons could be made as one study allowed two comparisons[141]. Four of the twelve studies were based on advergaming and not television[142–145]. Of the remaining eight studies five came from University of Liverpool in the UK[11,13,14,141,146], two from Radboud University in the Netherlands[147,148] and one from Yale University in the US[149].

Of the eight television advertisement based studies, four studies were between-subject comparison[141,145,147–149], meaning that participants were randomised to one exposure or the other and the two groups then compared. The remaining four studies were within-subject comparison[11,13,14,146], meaning all participants had both exposures and a comparison was made between their response to one exposure versus the other.

All four within-subject trials were undertaken at University of Liverpool. The first of these trials, by Halford et al in 2004[11], involved showing 8 advertisements for either food items or non-food related items to children aged 9-11 years. This was followed by a 10-minute cartoon. Children's ability to recall the advertisements was tested and they were then given a plate of four foods (Wholegrain crackers, Haribo jelly sweets, chocolate and butter puffs) and allowed to eat as much or as little as they liked. Following a two-week wash out period, the children were exposed to the alternate advertisements and a similar procedure was employed as per the first exposure. Following the second exposure the children's height and weight were recorded. The results found that overweight/obese children had greater recall of the food advertisements than healthy weight children. The overweight/obese children consumed more food in total than the healthy weight children. Overall, participants ate more of the sweet foods (jellies and chocolate) and the high fat-food (butter puffs) after watching food adverts when compared with the non-food adverts. This effect was more marked in the overweight/obese children than the healthy weight children. Healthy weight children ate more of the low-fat crackers after watching the non-food adverts.

A later study by the same authors had a similar design but the participants were 5-7 year old children[14]. Again, the authors found that the adverts affected dietary intake for all children. Unlike the previous trial, weight status did not affect the scale of the outcome.

A further study by the same authors, published in 2008, had a similar design and investigated 9-11-year-old children again[146]. The results of this study reinforced Halfords *et al's* earlier findings that not only do the adverts for foods result in greater intake of total and unhealthy food items compared to the control adverts, but that the increase in intake was associated with the children's weight status.

The final of the four within-subject randomised controlled trials involving children was published in 2011[13]. In this study, three interventions were used a cartoon with adverts embedded for healthy foods, unhealthy foods and toys. This was followed by a 15-minute period of eating from a standardised selection of healthy and unhealthy food items. Participants had their height and weight measured as in previous studies. It was found that food adverts, regardless of whether they were healthy or unhealthy, increased food intake compared with the toy adverts. The results reinforced the ability of unhealthy food advertisements to have a beyond-brand effect on unhealthy dietary intake. However, healthy food adverts did not have the effect of increasing intake of healthy food items- apart from in children with low levels of food neophobia. Like Halford *et al's* study of 5-7 year-old children, the response to the food adverts was not significantly affected by the children's weight status.

With regards to the four between subject trials, in Anschutz *et al's* 2009 trial of 8-12 year old children[147], children exposed to food commercials exhibited greater recall of the food commercials than neutral commercials. BMI and age were not significantly related to food intake. The authors reported that intake of the test food (Chocolate M&Ms) was higher in boys who watched the food adverts but lower in girls who watched the food adverts compared with the neutral adverts. In a similar trial by Anschutz *et al*[148], the authors investigated the effect that maternal encouragement to be thin has on children's response to food advertising. Contrary to expectations, children who perceived maternal encouragement to be thin ate slightly more when exposed to energy dense food advertisements compared with neutral advertisements. Furthermore, children with no perceived maternal encouragement to be thin ate more when exposed to neutral adverts compared with the energy dense food adverts.

In Harris *et al's* trial[149], both adults and children were included in the trial but were analysed separately. 118 children participated and were randomised to watching a cartoon with either advertisements for food or non-food products. Children were given a pre-weighed bowl of crackers and water during the cartoon and told they could eat as much or as little as wanted. The remaining crackers were weighed and the amount consumed recorded. Children's height, weight and demographic information was obtained from parents as well as their television watching habits. The results of the study reinforced the effect that food advertisement can have on children's consumption. Children who saw the food advertisements consumed 45% more crackers than the children that watched the non-food advertisements. Neither weight status, ethnicity, gender nor a multitude of television watching related characteristics were associated with the children's consumption in response to the adverts. The authors conclude that regardless of the child characteristics examined, children consumed more after viewing the food advertising.

The final between-subject trial included in Boyland *et al's* systematic review and meta-analysis was a trial undertaken in 2013 by Boyland *et al*[141]. The trial provided two comparisons for meta-analysis. The aim of the study was to investigate the effect that a premium sports celebrity endorser has on children's food choice and consumption. The participants were aged 8-11 years-old. They viewed a cartoon with one of four clips embedded: a commercial for Walkers crisps featuring a sports celebrity endorser, a commercial for another savoury food, footage of the sports celebrity as a presenter on a sports programme or an advertisement for a non-food product. The children were then presented with two labelled bowls of crisps, one labelled as the endorsed brand and the other as a supermarket brand. In reality, despite the labelling, both bowls of crisps contained the endorsed brand. The children's consumption was then measured. Overall, children consumed more of the endorsed brand. Looking at the individual advertisements, children consumed more of the endorsed brand for all advertisements apart from the non-food item. The findings of this study indicate that viewing a celebrity endorser in a non-food context can result in a similar response with regards dietary choices and intake amongst children.

6.4.10 The Effect of Television Advertising on Beverage Intake

It has been reported that watching more television results in unhealthy food and beverage choices. Despite this, only one study which measured beverage consumption met the inclusion criteria for Boyland *et al's* systematic review although it was not included in the subsequent meta-analysis because of a lack of access to the required data[150].

The trial was a between subject randomised controlled trial. Participants were all female adults and the exposure was a 35-minute movie clip with advertisements for soda or water. A pre-experiment self-reported visual analogue scale was used to assess thirst. The participants were given soda and water to drink during the movie. At the end of the movie, the weight of soda and water consumed was measured. The results demonstrated that participants assigned to the soda advertisements consumed 1.3 ounces (36.9ml) more soda than those who watched the control advertisements.

No such trials were could be found examining a similar effect in children. In addition, no similar trials were found which combined assessment of food and drink consumption. As such, the current trial serves to fill a void in the evidence base.

6.5 Predictors of Children's Response to Advertising

The association between childhood obesity and hours spent watching television has been established earlier (See section 6.3.1). It has been suggested that this effect is due to exposure to unhealthy food and drink advertising. However, it is possible that children would have a varying response to unhealthy food and drink advertising. Furthermore, children with a greater response to the advertisements may share certain characteristics.

For example, watching advertisements for unhealthy food and drink products may have a greater effect on children who are overweight or obese when compared with children who are healthy weight. Alternatively, children with experience of tooth decay may have a greater response to advertisements for high sugar food and drink products than children with no experience of tooth decay. Finally, a child's socioeconomic status may impact on their response to unhealthy food and drink advertisements.

It should be noted that, should an association between a characteristic and the children's response to unhealthy food advertisements be found, causality would be difficult to establish.

6.5.1 Children's Weight Status

Of the eight studies that investigated the acute effect that unhealthy food and drink television advertising has on children's dietary intake, all included an assessment of the children's weight status. Of these, six studies[13,14,141,147–149] reported no statistically significant association and two studies[11,146] reported a significant positive association. Both studies which found a significant association were within-subject trials and both were conducted by the same lead author.

6.5.2 Children's Experience of Dental Caries

There is very limited evidence with regarding an association between children's response to cariogenic food and drink advertisements and their experience of dental caries. There are no studies, to the authors knowledge, which measure actual food and beverage intake in response to advertisements for cariogenic food and drink items and associate this with dental caries experience. However, a recent study has investigated an association between children's food preferences, as measured by ticking photographs of various foods, and their dental caries experience[151].

Gatou *et al* undertook a within-subject trial of 183 eleven and twelve-year-old children. Information regarding the children's dietary habits, leisure activities and socioeconomic status were collected. In addition, the children's BMI was calculated and a dental examination was undertaken to establish their DMFT score. The children watched a 20-minute cartoon with eight advertisements embedded. The advertisements were for either cariogenic food and drink products or non-food products. The children's food preference was assessed by ticking on a card a selection of food items they would like to eat after watching the cartoon. Each child's preferences could then be compared for the two exposures. The authors report that no main effect of the advertising was found on children's food preferences. However, it was found that children with a higher DMFT selected a significantly higher percentage of unhealthy foods after exposure to the cariogenic food and drink advertisements in comparison with the non-food and drink advertisements.

6.5.3 Children's Socioeconomic Status

There is limited evidence with regards to an association between children's dietary intake in response to unhealthy food and drink advertisements and their socioeconomic status. Although highlighted as a potential confounding factor by Halford *et al*[14], no subsequent similar studies included an assessment of socioeconomic status in their design. In Gatou *et al's* food preference trial[151], the children's socioeconomic status was recorded however no statistically significant association was reported. However, as the authors point out, their trial measured food preference by children ticking images of food rather than measuring actual food intake.

7 Research Methods

7.1 Study Design

The design of this study was a cross-over randomised controlled trial (RCT). A cross-over RCT is a repeated measures trial where participants are randomly allocated to one arm of the trial during the first study period and automatically allocated to the alternate arm for the second study period. It allows comparison of the two interventions within each participant- hence the term within-subject comparison[152].

When compared to standard parallel-arm trials where between-subject comparisons are made, cross-over trials have two key advantages[153]. Firstly, although the randomisation process in the parallel arm RCT's reduces the risk of covariate imbalance, due to the number of potential covariates, imbalance often exists. In cross-over trials, the risk of imbalance is minimised as each participant acts as their own control. The second key advantage is that each subject participates in the study twice, thus minimising the number of participants required.

The disadvantages of cross-over trials include "order" effects, the "carry-over" effect and "learning". Order effects refer to the possibility that the order in which treatments are administered may affect the outcome. To reduce this effect, randomisation of participant allocation during week one of the trial was undertaken. The carry-over effect is the risk that the effect of the first exposure impacts on the outcome of the second exposure. To reduce this risk, a wash-out period is required to allow the effect of the first intervention to dissipate. The length of the wash-out period required varies depending on the intervention used. The wash-out period used for the current trial was two weeks and is in keeping with previous similar trials[11,146]. Finally, "learning" refers to the fact that knowledge of an intervention based on the first exposure may affect the response of an individual to the second exposure.

Randomisation of allocation during week one should reduce the impact that learning may have on the overall outcome of the trial.

7.2 Study objectives

The objective of this study was to assess if children consume more calories and/or sugar in response to watching high sugar food and drink advertisements when compared to non-food/drink advertisements. Also, to investigate the relationship between the children's response to the advertisements and their experience of dental caries, their weight status and their socioeconomic status. Finally, to investigate the relationship between the children's caries experience, weight status and socioeconomic status.

7.3 Participants

7.3.1 Location

The participants were all pupils at a primary school in the North West of England.

7.3.2 Sample size

The sample size was based on a previous similar within-subject trial undertaken at the University of Liverpool which found a significant outcome with regards the effect that advertisements have on children's dietary intake as measured in kilocalories[14]. The sample size in the referenced trial was 93 children. As such a target sample size of 100 children was set to meet the sample size of the referenced trial while allowing for a small number (<10%) of dropouts.

7.3.3 Participant age

The age range of participants to be invited to participate was set as 7-11y. Previous similar trials have used a variety of age groups 5-7y[13,14], 7-10y[154], 9-11y[11,146]. The age range of 7-11y was chosen to allow us to meet our sample size requirements. Year 4 and year 5 were to be invited first and should further participants be required, year 3 and year 6 could also be invited.

7.3.4 School and Participant Consent

The primary school was selected as they had participated in research undertaken by The University of Liverpool in the past. Contact was made with the school head teacher who agreed to allow the current study to take place. In March 2016, a meeting was held with the headteacher and she completed a consent form for the school to partake in the study**.**

Prior to the study, 120 participant consent forms were sent to the parents of all children in year 4 and year 5. Consent forms were sent to 120 pupils due to the likelihood of some parents not providing consent. The consent forms included information regarding the methods of the study including the food and drinks being provided. Parents provided their postcode and consent for this to be used to calculate an Index of Multiple Deprivation score for each participant. In total, parental consent was received for 104 children to participate.

7.3.5 Participant Medical History

As part of the parental information and consent form, parents were asked to confirm that their child did not have any intolerance or allergy to the food and drinks being used in the study. Prior to commencement of the study, the consent forms were checked to ensure that no children were precluded from involvement due to food or drink intolerance or allergy.

7.3.6 Participant Socio-economic Status

As part of the parental information and consent form, parents were asked to provide their child's postcode. They also consented for this to be used to calculate an Index of Multiple Deprivation score for their child**.** The Index of Multiple Deprivation (IMD) is a UK government study of deprived areas in English local councils. It covers seven aspects of deprivation including:

- Income
- Employment
- Health deprivation and disability
- Education, skills and training,
- Barriers to housing and services
- Crime
- Living environment

Each child's postcode was entered into an online tool which returns an IMD score and IMD Quintile (1 being the least deprived and 5 being the most)[155]. The children's IMD Quintile was used in the statistical analysis.

7.3.7 Inclusion Criteria

The inclusion criteria for participation in this study were:

- To be a pupil at the primary school taking part
- To be between the ages of 7 to 11 years
- To have a signed parental consent form
- To provide positive affirmation of his/her wish to participate.

7.3.8 Exclusion criteria

Potential participants were excluded if they:

- Had a history of anaphylaxis to any of the food or drinks involved in the study
- Had a known allergy or intolerance to any of the food and drinks involved in the study
- Were not of the appropriate age
- Did not have parental consent
- Did not wish to participate themselves
- Had parents/guardians who could not understand written English

7.3.9 Affirmation of wish to participate

Prior to commencement of the study, the 104 participants were gathered at an assembly. The children were told that they would watch a cartoon and that they would have some food and drinks afterwards. They were also advised that their height and weight would be measured and a dental examination would be undertaken. They were reassured that the height and weight measurements and dental examination would not be undertaken in the presence of their peers and that the results would be used anonymously. Children were given an opportunity to ask any questions. The children were told that the researchers were from the University of Liverpool however they were not told that some of the researchers were dentists.

Children were then asked to exit the assembly and were allocated a participant number in the order that they left the room. In addition, the children provided positive affirmation of their willingness to participate as they left the assembly.

7.3.10 Randomisation of sample

Having been allocated a study participant number on exiting the assembly the children returned to their classrooms. An online randomised number sequence generator[156] was used to divide the sample into two groups. One group watched the cartoon with cariogenic food and drink adverts during week one of the trial and the same cartoon but with toy adverts during week two of the trial. The other group watched the cartoon with the toy adverts during week one of the trial and the same cartoon but with cariogenic food and drink adverts during week two of the trial.

7.4 Intervention

7.4.1 Setting and seating arrangement

The trial took place in a self-contained building on the school property that is usually used for the school's before and after school clubs. The building has two levels, the upper level was used to conduct this trial. On the upper level, there were three rooms: a kitchen, a classroom with a projector (see figure 3) and a small art room with tables and chairs. All food was prepared and weighed in the kitchen area and laid out on trays in the art room in preparation for the next group of children (see figure 4). The trial took place in the classroom. For convenience, the children were divided into subgroups, each subgroup contained children scheduled to watch the same intervention. Children were called from their classes and assembled at the secretary's office. The children were escorted from the secretary's office to the classroom. The doors of the kitchen area and art room remained closed as the children entered the classroom. Once in the classroom, the children sat at one of two tables with a clear view of the projector screen. Each child confirmed they could see the screen comfortably.

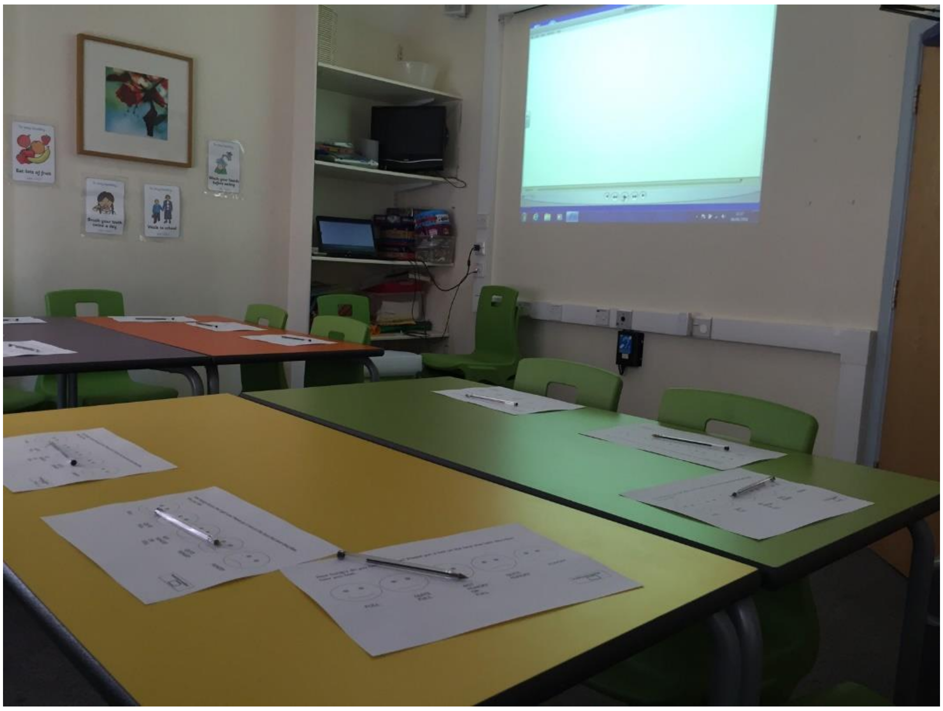

Figure 3: Photograph of the research setting with projector

Figure 4: Standardised trays of food and drink

7.4.2 Assessment of hunger

Once all children were seated, a numbered sticker corresponding to each child's participant number was placed on their shirt. The children were then given a pen and a sheet of paper with a 5-point Likert scale to indicate their hunger-level (see appendix 1). Each child's participant number was written at the top of their sheet. They were then instructed to tick a smiley face in accordance with their level of hunger, an explanation of what the various smiley faces mean was given. The sheets were then collected and filed.

7.4.3 Cartoon and advertisements

An age-appropriate cartoon was sourced (Scooby-Doo, Chapter 34, Night on Haunted Mountain). The cartoon was 21 minutes long and a movie editing programme was used to insert four 30-second advertisements at the mid-point. The advertisements were for either cariogenic food and drink items or for toys depending on the children's allocation (See table 4 below).

High sugar food/drink advertisements	Non-food/drink advertisements
McVitie's® Digestive Biscuits	Xeno® Interactive Monster
Haribo® Starmix	VTEch® Kidizoom Smart Watch
Lucozade® Energy drink	Y·volution® Y-Fliker Scooter
Fanta® Orange drink	H2O Go® Waterslide

Table 4: Television advertisements used in this study

7.4.4 Food and Drink

Prior to the children attending the study setting, a standardised transparent plastic tray of food and drink was prepared for each child (See table 5 for details). A numbered sticker was placed on each tray to correspond to the children's participant number. A corresponding data collection sheet was numbered for each tray. The four food items were placed into plain white bowls and weighed using a digital food scale accurate to 1 gram (Salter 1036-SVSSDR**.** In addition, the two drink items were decanted into identical, unlabelled, clear plastic bottles and weighed. The bottles had a sports cap to prevent spillages (see figure 5). The pre-consumption weights were recorded for each food and drink item on the corresponding data collection sheet (See appendix 2).

Figure 5: Standardised, pre-weighed, unlabelled tray of food and drink

After watching the cartoon with their allocated advertisements, the numbered trays of food were served to their correspondingly numbered participant. The children were advised that they could eat as much or as little of each item as required and that should they finish a bowl or bottle of food or drink that they could request more of that item. The children were also advised that it was not permitted to share food and that all food/drink must be kept on the trays. If a child requested more food or drink, the new item was weighed and the pre-consumption weight added to their numbered data collection sheet.

High Sugar Foods and Drinks	Low Sugar Food and Drinks
Chocolate buttons	Grapes
Jelly sweets	Carrots
Orange Juice from Concentrate	Water

Table 5: Food and drinks used in this study

The children were given 15 minutes to eat or drink as much as they wished. A time limit was placed so as not to unduly disrupt the school's curriculum. The 15-minute time limit had been used in a previous similar study[13]. After the 15-minutes had elapsed, the children were asked to leave the study area. Care was taken to ensure children did not take any food items with them at the end of the trial.

When the children had left, each participants tray was matched to their data collection sheet and the remaining food and drink items were weighed individually. The post-consumption weight of each item was recorded on the data collection sheets. Following this, the data collection sheet was filed for later analysis.

During week two, children were called in the same subgroups as per week one. Every effort was made to ensure that the children took part on the same day of the week and time of day as week one. The children attended the same setting and, as week one, a sticker was placed on each child's shirt with their participant number. The children completed the same pre-consumption hunger assessment Likert questionnaire. After this the children watched the same cartoon as week one but with the alternate advertisements embedded. After watching the cartoon, the children were given the same instructions as in week one. The food and drink items were weighed, recorded and served as week one. The children were given 15 minutes to eat and drink as much as they wished and further servings of any food or drink item could be requested as week one.

Unlike during week one, after completion of the 15-minute period, children did not return to their classrooms immediately after the food and drink intake assessment. Instead they remained in the study area for the height and weight measurement and the dental examination.

7.4.5 Assessment of height and weight

During week two, once the trays had been collected for each subgroup, the children had their height and weight measured. To ensure confidentiality, the children were called from the classroom individually. One researcher (GK) undertook all measurements. The children's height was measured in centimetres using a stadiometer accurate to 0.5 centimetres (Leicester Portable Height Measure: SECA). The children's weight was measured in kilogrammes using a digital scale accurate to 0.2 kilogrammes (SECA 875 Flat Scales) (see figure 6). Twelve children had their height and weight measured on separate occasions to measure intra-examiner reliability of the height and weight measurements. The height and weight for each child was recorded on a data sheet for each child along with their participant number (see appendix 3**)**.

Figure 6: Stadiometer and weighing scales

The children's height and weight measurements were used to calculate a BMI score. Using Cole *et al's* revised 2000 reference standards[24], the BMI score was used to categorise the participants weight status as either healthy weight or overweight/obese.

7.4.6 Dental Assessment

Once each child had had their height and weight measured a dental examination was undertaken. The dental examination was limited to the condition of the four first permanent molars. A DMFT score was allocated which ranged from 0-4 in accordance with the number of decayed, missing or filled teeth. A decision was taken to limit the dental examination to the four first permanent molars as:

- These teeth would be present in all children
- The children were at various stages of the transition from deciduous (baby) teeth to permanent teeth. A recognised shortcoming of the DMFT is that assumptions are made with regards the caries experience of exfoliated deciduous teeth.

The dental examination involved a visual inspection using a high-powered head-torch (Energizer Vision HD+ Focus headlight- 300 Lumens). A disposable mirror and probe (Kerr TotalCare-Sterile dental mirror and periodontal probe) were used to explore the tooth surfaces. Sixty-six of the children were assessed by both dentists independently and the remainder by one dentist (JK). This allowed for the assessment of Inter-examiner reliability. A DMFT score was documented for each child on the appropriate data collection sheet (See Appendix 4). As the purpose of the dental assessment was to assess if caries experience was associated with the other variables in the study, the DMFT score was converted to a dichotomous yes/no caries experience.

7.5 Comparison

7.5.1 Within-subject comparison of consumption

The design of this study allowed a comparison each child's response to cariogenic food/drink advertisements with their response to the toy advertisements. Due to the nature of the cross-over study design, and the care taken to ensure that the experimental conditions were as close to identical as possible across the two interventions, confounding effects should be minimised.

In addition to the primary objective, the response of the children (in terms of kcal and grams of sugar consumed) between the two exposures was explored in relation to their:

1) Dental caries experience: Yes compared with No
2) Weight status: Healthy weight compared with overweight/obese
3) Socioeconomic status: Comparing the 5 quintiles from the IMD scores.

7.6 Study objectives

7.6.1 Primary objectives and outcomes

The primary objective of this study was to investigate the difference in food and drink consumed by the children (as measured in kcal and grams of sugar) after watching the cartoon with advertisements for cariogenic food and drink items compared with the same cartoon with advertisements for toys.

7.6.2 Secondary objectives

The secondary objectives of this study included:

- The difference between the children's response (as measured in kcal and grams of sugar) to the change in advertisements in those children with experience of dental caries compared with those children without experience of dental caries
- The difference between the children's response (as measured in kcal and grams of sugar) to the change in advertisements in those children with a healthy weight status compared with an overweight/obese weight status
- The difference between the children's response (as measured in kcal and grams of sugar) to the change in advertisements across the five Index of Multiple Deprivation quintiles.
- The relationship between the children's dental caries experience, weight status and socioeconomic status.

7.7 Handling of Data

Following completion of the trial, the data was inputted into an Excel® spreadsheet. Participant factors were recorded such as gender, age, day of week and time of participation, subgroup number, and allocation for week one. The amount consumed by each child for the food and drink items was calculated by subtracting the post-consumption weight of the bowl/bottle and contents from the pre-consumption weight. This was then used to calculate the number of kilocalories consumed and grams of sugar consumed per food/drink item using the manufacturer's nutritional content information (See Table 6). Following this, the total amount consumed in kilocalories and grams of sugar was calculated for each child and for each week. This allowed for comparison of consumption across the two interventions.

Food/Drink	Kilocalories per 100g	Grams of Sugar per 100g
High Sugar Food and Drink Items:		
Chocolate buttons	540	54.4
Jelly sweets	345	55
Orange Juice	47	10.5
Low Sugar Food and Drink Items:		
Grapes	66	13
Carrots	42	7.2
Water	0	0

Table 6: Nutritional content of food and drink consumed

An equation was used to calculate the children's BMI based on their height and weight measurements:

$$BMI = Weight/Height^2$$

Children were then categorised as healthy weight or overweight/obese based on age and gender specific BMI cut-offs[24].

The children's DMFT score, based on the status of their first permanent molars, was converted to a dichotomous outcome. A DMFT score of 0 indicating no experience of dental caries. A DMFT score of 1,2,3 or 4 indicating experience of dental caries.

Each child's postcode was manually entered into an online tool[155] that generated an IMD score and IMD Quintile which were added to the Excel spreadsheet.

Following this, all data were transferred to IBM® SPSS® Statistics Version 24 for Windows (SPSS Inc., Chicago, US) for statistical analysis.

7.8 Statistical Analysis

7.8.1 Baseline characteristics of sample

To establish the baseline characteristics the following data was explored:

- Number of participants meeting the inclusion criteria
- Number and reason for exclusion of participants
- Mean age of children in sample was calculated
- Frequency of male and female participants

7.8.2 Comparison of pre-consumption hunger levels between interventions

In order that any differences in intake could be attributed to the experimental manipulation and not in differences in hunger on the two occasions, it was necessary to compare children's ratings of hunger on both occasions. A paired t-test was used to establish if a statistically significant difference existed between the Likert ratings of hunger completed by each child at the start of each testing session.

7.8.3 Assessment of Normality of Distribution:

The difference in the children's intake, as measured in kilocalories and grams of sugar, between the two interventions was plotted and assessed visually for normality of distribution. This was due to the contention that for larger sample sizes (>100), tests such as

Shapiro-Wilks test and Kolmogorov-Smirnov test can be overly conservative and the assumption of normality might be rejected too easily[157,158].

7.8.4 Intra-examiner reliability of height and weight measurements

Intra-class correlation co-efficient (ICC) was used to calculate intra-examiner reliability of the duplicated height and weight measurements.

7.8.5 Inter-examiner reliability of dental assessment

Cohen's Kappa statistic was used to calculate the inter-examiner reliability of the duplicated dental examinations.

7.8.6 Within-subject comparison of consumption between exposures:

To address the primary aim of the study, paired t-tests were used to examine the mean difference between children's food/drink intake in kilocalories (kcal) and grams (g) of sugar when exposed to the cariogenic food/drink commercials versus their food/drink intake when exposed to the toy commercials.

For the purposes of analysis and discussion, a "response to advertisement" variable was calculated by subtracting each child's food and drink consumption after viewing the toy advertisements from their consumption after viewing the cariogenic food/drink advertisements.

7.8.7 Within-subject comparison of individual food and drink item consumption

To determine the effect of the advertisements on the children's consumption of the individual food and drink items, paired t-tests were used to compare their consumption between conditions. Individual tests were conducted for grams of sugar consumed and kilocalories consumed.

7.8.8 Influence of gender on the children's response to the interventions

To investigate the influence that the children's gender may have had on their response to change of intervention, an independent sample t-test was used. The children's response to the advertisements (measured in kilocalories and grams of sugar) was set as the test variable and children's gender was set as the grouping variable.

7.8.9 Influence of dental caries experience on the children's response to the change in advertisements

To investigate the influence that the children's dental caries experience status may have had on their response to the advertisements, an independent sample t-test was used. The children's response to the advertisements (measured in kilocalories and grams of sugar) was the test variable. The children's caries experience (yes or no) was set as the grouping variable.

7.8.10 Influence of weight status on the children's response to the change in advertisements

To investigate the influence that the children's weight status may have had on their response to the advertisements, an independent sample t-test was used. The children's response to the advertisements (measured in kilocalories and grams of sugar) was the test variable. The children's weight status (healthy or overweight/obese) was the grouping variable.

7.8.11 Influence of socioeconomic status on the children's response to the change in advertisements

To investigate the relationship between the children's socioeconomic status and their response to the advertisements (measured in both kilocalories and grams of sugar), one-way ANOVA was used. The response of the children to the advertisements measured in kilocalories and grams of sugar were set as the dependent variables. The Index of Multiple Deprivation quintile was set as the Factor.

7.8.12 Regression Analysis

Univariate linear regression analyses were undertaken with the children's response to the adverts as measured in kilocalories and grams of sugar set as dependent variables. The children's caries experience, weight status and socioeconomic status were potential independent variables. If, following the independent sample t-tests, the independent variables were found to be associated with the dependent variables with a p-value of >0.2 they would be omitted from the univariate linear regression analysis.

7.8.13 Investigation of the relationship between the children's caries experience, their weight status and their socioeconomic status

To investigate an association between the children's caries experience, weight status and their socioeconomic status, Pearson's Chi Square Test was used. This test was chosen as all of these variables were converted to categorical data.

7.8.14 Investigating potential confounding factors

Although every effort was made to ensure that the children’s test conditions were as close as possible between week one and week two, it is possible that confounding factors outside of our control may have had an effect. For example, temperature changes may have resulted in greater consumption of liquids on one occasion relative to the other. To investigate if any significant differences in intake (kilocalories or grams of sugar) existed between the two weeks a paired t test was performed which compared children’s intake during week one to their intake during week two, irrespective of the intervention received.

8 Results

8.1 Baseline characteristics of sample

120 consent forms were distributed to parents prior to commencement of the study. A sample size of 100 children was targeted. 104 parents consented for their child's participation. The participating children attended an assembly, at which an outline of the trial was discussed. All 104 children affirmed their wish to participate. Of the 104 children, 101 children completed both weeks of the trial. Three children missed the second week of the trial due to absence from school- as such their data was omitted from the analysis.

8.1.1 Age of Sample

Participants were aged from 8 years to 10 years old and the mean age of the sample was 9.86 years old.

Number of Participants	Age Range	Mean Age	Standard Deviation
101	8.8y- 10.8y	9.9	0.5

Table 7: Age characteristics of participants

8.1.2 Gender of Participants:

The final sample of 101 children consisted of 61 females and 40 males.

8.1.3 Comparison of pre-consumption hunger levels between interventions

To assess hunger, the children ticked a box on a scale of 1-5 indicating their level of hunger prior to each intervention (box 1 indicated not hungry, box 5 very hungry). One child failed to tick a box during the second week meaning 100 participants were included in the comparison. A paired sample t-test was used to compare the hunger levels between interventions.

The children reported a mean hunger score of 4.22 (out of 5) prior to watching the cartoon with the advertisements for sweet food and drink items. They reported a mean hunger score of 4.19 prior to watching the cartoon with advertisements for toys. Although a mean difference of 0.03 was found, this was not statistically significant (95% CI: -0.15, 0.21. p=0.74). (See tables 8 and 9). Therefore, hunger was not included in any subsequent analyses.

	Mean Score	Number of Participants	Standard Deviation	Standard Error of the Mean
Hunger: Prior to Sweet Adverts	4.22	100	0.93	0.093
Hunger: Prior to Toy Adverts	4.19	100	0.93	0.093

Table 8: Self-reported levels of hunger prior to the interventions (1- Not hungry, 5-Very hungry)

	Mean difference	Standard Deviation	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Significance (2-tailed)
Hunger Sweet Ads: Hunger Toy Ads	0.03	0.89	-0.15	0.21	0.74

Table 9: Mean difference in self-reported hunger levels between exposures

8.1.4 Comparison of week one versus week two irrespective of the intervention

To investigate if any significant difference in kilocalorie intake or grams of sugar intake existed between the two weeks a paired t-test was performed which compared children's intake during week one with their intake during week two, irrespective of the intervention received.

The results demonstrated no statistically significant difference in neither the children's sugar intake ($p= 0.618$) nor the children's kilocalorie intake ($p= 0.819$). As such this did not have to be accounted in subsequent analyses (See tables 10 and 11).

	Mean	N	Standard Deviation	Standard Error Mean
Week 1: Mean Sugar Intake	75.82	101	32.96	3.28
Week 2: Mean Sugar Intake	77.13	101	39.56	3.94
Week 1: Mean Kilocalories Intake	524.59	101	235.58	23.44
Week 2: Mean Kilocalorie Intake	533.05	101	268.64	26.73

Table 10: Comparison of sugar intake between the two weeks of the trial irrespective of exposure

	Mean difference	95% Confidence Interval	P-value
Week 1: Week 2 Sugar Intake	-1.30	-6.48 to 3.87	0.618
Week 1: Week 2 Kilocalorie Intake	-8.47	-81.52 to 64.59	0.819

Table 11: Mean difference between the two weeks of the trial irrespective of exposure

8.2 Assessment of Normality of Distribution

The difference in the children's intake, as measured in kilocalories and grams of sugar, between the two interventions was plotted and assessed visually for normality of distribution.

8.2.1 Normality of Distribution of the Children's Response to the Change in Advertisements: Grams of Sugar.

A histogram was plotted of the difference between the children's sugar intake after watching the advertisements for cariogenic products compared to after watching the toy advertisements (See figure 7). The histogram demonstrates that the assumption of normality is reasonable. Therefore, parametric tests are appropriate with these data.

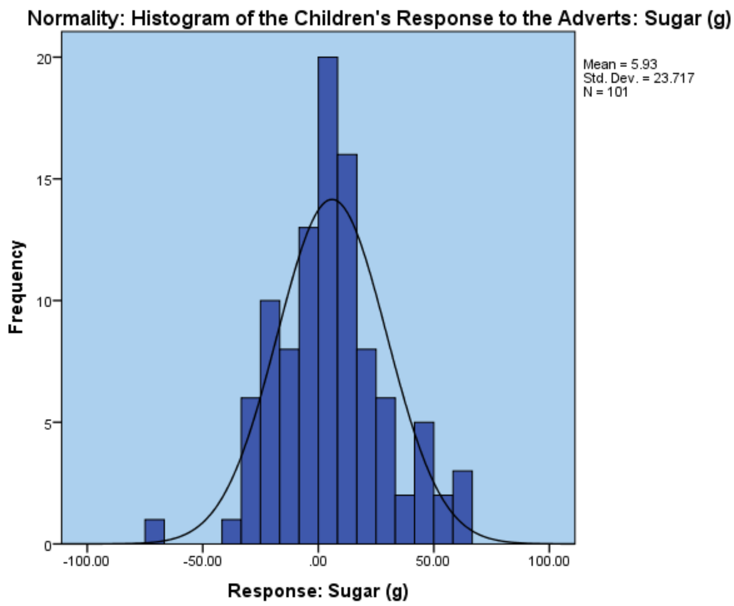

Figure 7: Histogram used to visually assess normality of distribution for the children's response to the advertisements measured in grams of sugar.

8.2.2 Normality of Distribution of the Children's Response to the Change in Advertisements: Kilocalories

A histogram was plotted of the difference between the children's kilocalories intake after watching the advertisements for cariogenic products compared to after watching the toy advertisements (See figure 8). The histogram demonstrates that the assumption of normality is reasonable. Therefore, parametric tests are appropriate with these data.

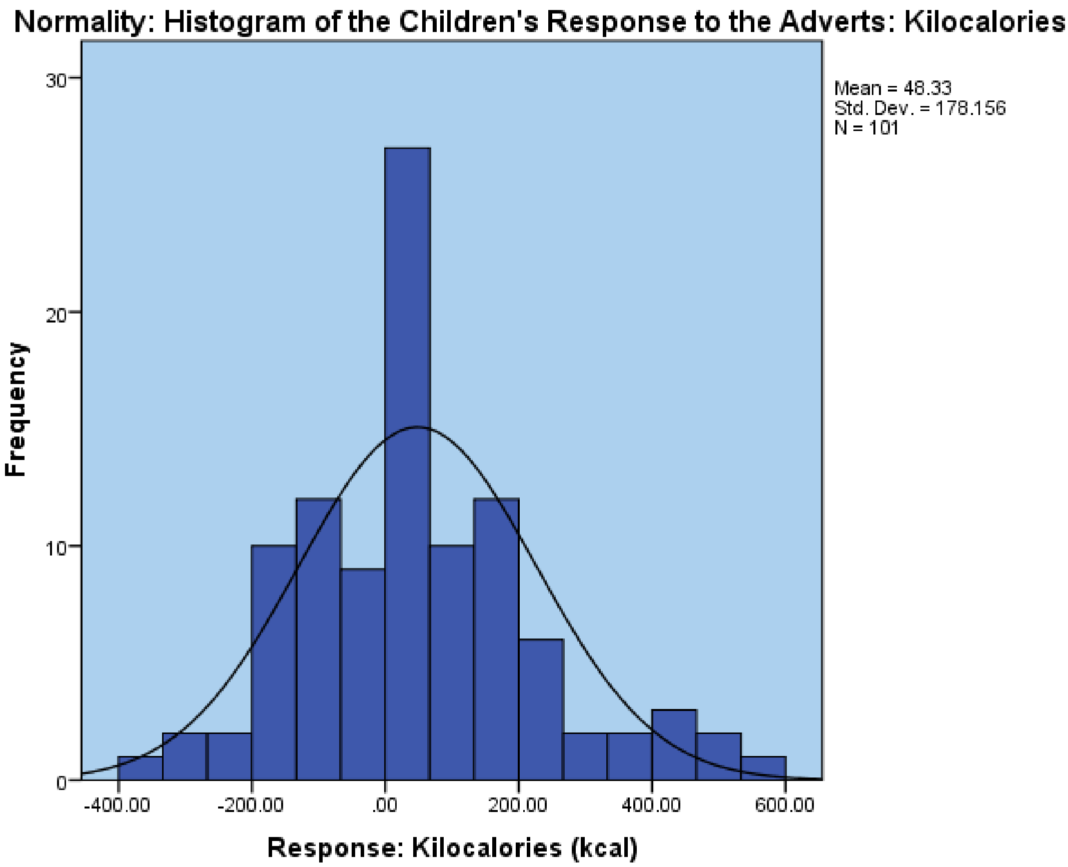

Figure 8: Histogram used to visually assess normality of distribution for the children's response to the advertisements measured in kilocalories

8.3 Reliability of measurements

8.3.1 Height and weight measurements

To investigate the reliability of the height and weight measurements twelve participants had their height and weight taken on two separate occasions. Intra-class correlation co-efficient (ICC) was used to calculate intra-examiner reliability of the duplicated height and weight measurements.

The ICC for repeat measures of both height and weight were very high (See table 12 and 13). Bland-Altman plots were constructed for both height and weight repeat measurements (See figures 9 and 10).

	Intra-class Correlation Co-efficient	95% Limits of Agreement	Estimated Within-Subjects Standard Deviation
Height	0.99	-0.62 to 0.79	0.25

Table 12: Repeatability of measurements for height

	Intra-class Correlation Co-efficient	95% Limits of Agreement	Estimated Within-Subjects Standard Deviation
Weight	0.99	-0.28 to 0.25	0.09

Table 13: Repeatability of measurements for weight

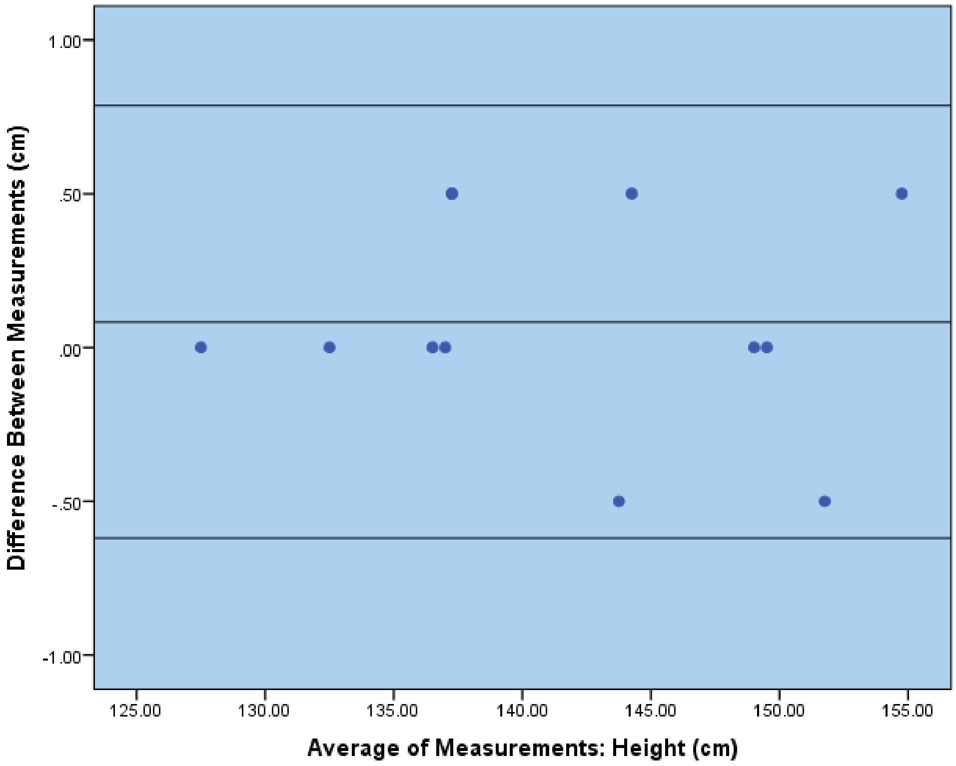

Figure 9: Bland-Altman plots for repeat measures of height

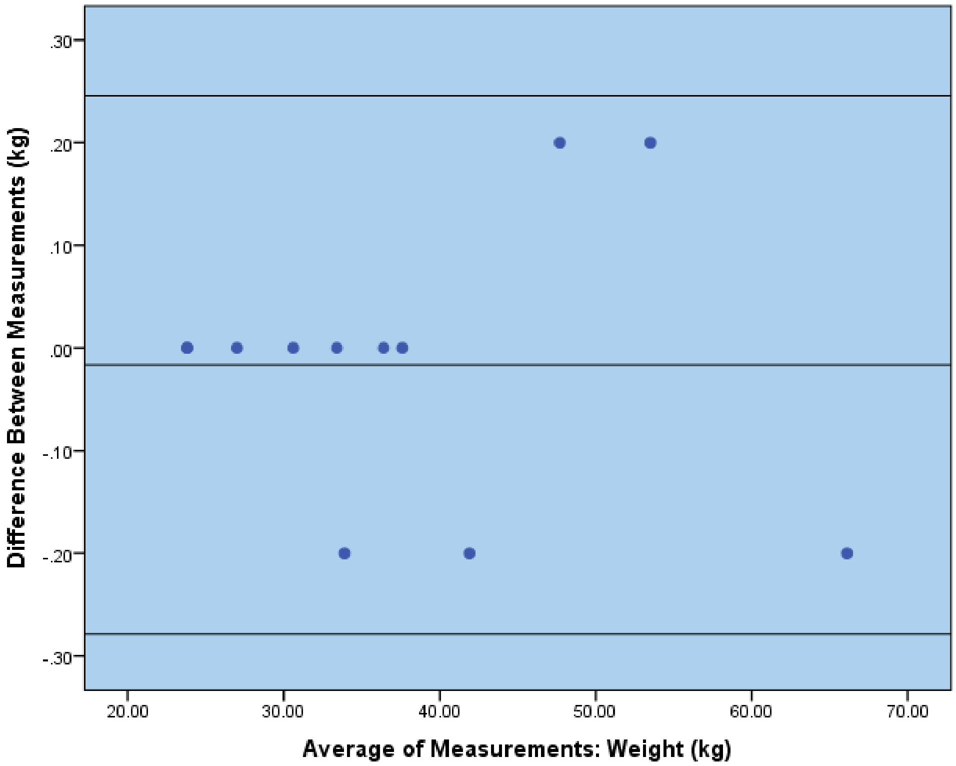

Figure 10: Bland-Altman plots for repeat measures of weight

8.3.2 Inter-examiner reliability of dental assessment

Sixty-six children were examined twice, once by JK and once by RF. Cohen's Kappa statistic was used to calculate the inter-examiner reliability of the duplicated dental examinations. Cohen's Kappa statistic for the duplicated DMFT measurements was 0.88. The observed agreement was very high at 96.97% (See table 14).

	N	Observed Agreement	Expected Agreement	Kappa	95% Confidence Interval
Dental Assessment	66	96.97%	75.16%	0.88	0.71 to 1.000

Table 14: Inter-examiner reliability of dental

8.4 Within-subject comparison of consumption between exposures

The primary aim of this study was to investigate if the children make different food choices after they had been exposed to advertisements for cariogenic food and drink items compared to after non-food advertisements. To establish this, paired t-tests were used to compare the children's intake following each intervention (See table 15).

The tests demonstrated a statistically significant difference in the children's intake between the two test conditions. Children consumed more sugar after watching the cartoon with advertisements for cariogenic food and drinks when compared with the non-food advertisements (Mean difference: 5.93 grams, 95% CI 1.25-10.61, p=0.014).

In addition, children consumed significantly more kilocalories after viewing the cartoon with advertisements for cariogenic food and drink when compared with the non-food advertisements (Mean difference 48.33kcal, 95% CI 13.16-83.50, p=0.008).

	N	Sweet adverts Mean (S.D.)	Toy adverts Mean (S.D.)	Mean difference (95% CI)	P-Value
Mean Sugar intake (g)	101	81.56 (33.22)	75.63 (36.62)	5.93 (1.25-10.61)	p= 0.014
Mean Calorific intake (kcal)	101	566.35 (229.90)	518.02 (255.73)	48.33 (13.16-83.50)	p=0.008

Table 15: Comparison of intake between conditions. Measured in grams of sugar and kilocalories

8.4.1 Within-subject comparison of consumption of individual food and drink items:

To determine the effect of the advertisements on the children's consumption of individual food and drink items, paired t-tests were used to compare their consumption for both conditions.

The results demonstrate that children consumed a higher amount of sugar and kilocalories from the jelly sweets after watching the advertisements for cariogenic products compared with the non-food products (Sugar: Mean difference 4.21g, 95% CI 1.41 to 7.02, p= 0.004. Kilocalories: Mean difference 26.43kcal, 95% CI 8.85 to 44.03, p=0.004)

No statistically significant difference was found for any other food/drink item (See tables 16 and 17).

Food/Drink	Toy Advertisements Sugar (g)	Sweet Advertisements Sugar (g)	Mean Difference	95% Confidence Interval	Sig.
Orange Juice	13.95	13.33	-0.61	-2.95, 1.72	0.604
Carrots Sticks	1.89	1.81	-0.07	-0.51, 0.36	0.740
Grapes	11.833	11.62	-0.21	-1.89, 1.46	0.801
Chocolate	25.46	28.08	2.62	-0.26, 5.49	0.074
Jelly Sweets	22.50	26.72	4.21	1.41, 7.02	0.004

Table 16: Consumption of individual food/drink items- measured in grams of sugar.

Food/Drink	Toy Advertisements Kilocalories	Sweet Advertisements Kilocalories	Mean Difference	95% Confidence Interval	Sig.
Orange Juice	62.43	59.69	-2.75	-13.21, 7.72	0.604
Carrots Sticks	11.00	10.57	-0.43	-2.98, 2.12	0.740
Grapes	50.72	49.80	-0.91	-8.09, 6.26	0.801
Chocolate	252.73	278.71	25.98	-2.57, 54.53	0.074
Jellies Sweets	141.14	167.58	26.43	8.85, 44.03	0.004

Table 17: Consumption of individual food/drink items- measured in kilocalories.

8.5 Influence of Gender on the Children’s Response to the Change in Advertisements

Independent sample t-tests were used to compare the boys’ response to the change in advertisements to the girls’ response to the change in advertisements. The mean response was higher for boys than for girls with regards to sugar intake. However, this difference was not statistically significant. (Boys mean response 7.26g, Girls mean response: 5.06g Mean Difference: 2.20g, 95% CI -7.41 to 11.82, p=0.434)

Furthermore, the mean response to the change in advertisements was higher for boys than for girls with regards to kilocalories intake. However, again, no statistically significant difference was found. (Boys mean response: 53.08kcal, Girls mean response: 45.23kcal Mean difference: 7.85kcal, 95% CI: -64.42 to 80.12, p= 0.611). (See figure 11)

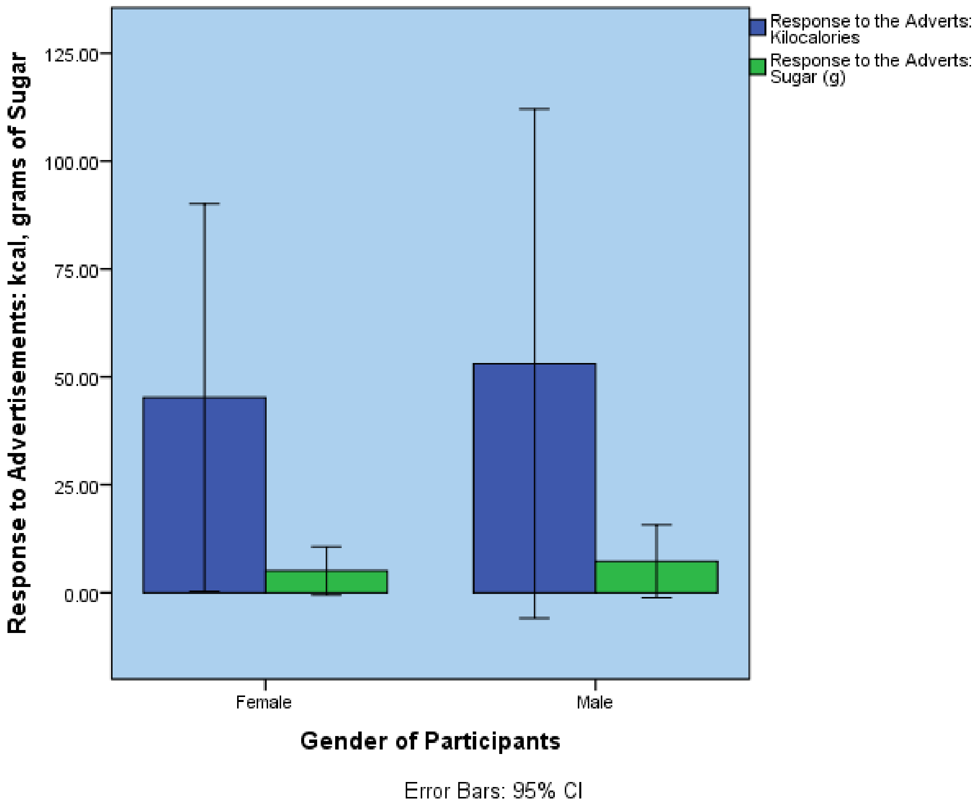

Figure 11: Comparison of boy’s and girl’s response to the change in advertisements. Measured in grams of sugar and kilocalories.

8.6 Influence of dental caries experience on the children's response to the change in advertisements

To investigate the influence that the children's dental caries experience status may have had on their response to the advertisements, an independent sample t-test was used.

The results showed that children with experience of dental caries had a greater response to the change in advertisements as measured in grams of sugar and kilocalories (12.16 grams of sugar and 86.54 kcal). This greater response was statistically significant for grams of sugar (95% CI 0.60 to 23.71, p= 0.039). However, it was not statistically significant for kilocalories (95% CI -0.48 kcal to 173.55 kcal, p=0.051). (See tables 18, 19, figure 12)

	N	Response to Change in Advertisements: Grams of Sugar	Response to Change in Advertisements: Kilocalories
No Caries Experience	81	3.53 g	31.20 kcal
Have Caries Experience	20	15.68 g	117.73 kcal

Table 18: Influence of dental caries experience on the children's response to the advertisements in grams of sugar and kilocalories

	Mean Difference	95% Confidence Interval	p-value
No Caries: Caries Sugar (g)	12.16g	0.60 g to 23.71 g	0.039
No Caries: Caries Kilocalories	86.54kcal	-0.48 kcal to 173.55 kcal	0.051

Table 19: Caries versus non-caries experience: Mean difference between the response of children to the advertisements

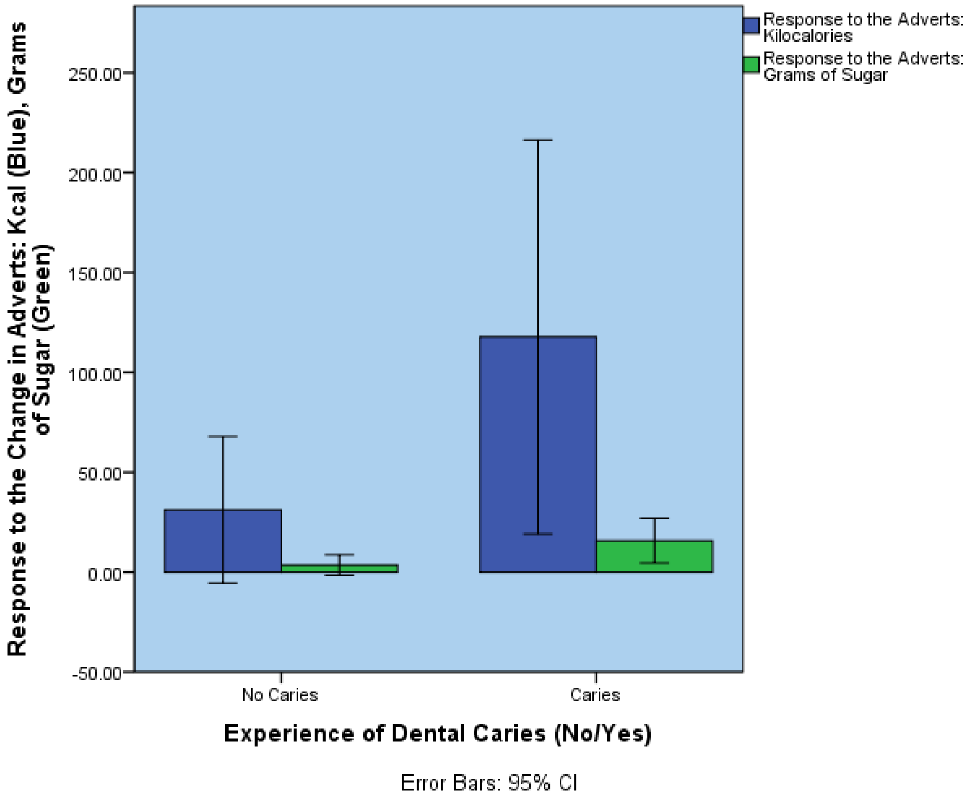

Figure 12: Influence of dental caries experience on the children's response to the change in advertisements

8.7 Influence of weight status on the children's response to the change in advertisements

To investigate the influence that the children's weight status may have had on their response to the advertisements, an independent sample t-test was used.

The results showed that overweight/obese children actually reduced their sugar intake in response to the change in advertisements whereas the healthy weight children increased their intake. However, the mean difference was not statistically significant (Mean difference 9.11g, 95% CI: -2.00g to 20.22g, p= 0.107).

In addition, overweight/obese children had a reduction in kilocalorie intake in response to the change in advertisements while the healthy weight children increased their intake. Again, the mean difference was not statistically significant (Mean difference: 81.77kcal, 95% CI: -1.17kcal to 164.70kcal, p= 0.053). (See tables 20 and 21)

	N	Response to Change in Advertisements: Grams of Sugar	Response to Change in Advertisements: Kilocalories
Healthy Weight	77	7.58 g	64.16 kcal
Overweight/Obese	22	-1.52 g	-17.61 kcal

Table 20: Influence of weight status on the children's response to the change in advertisements

	Mean Difference	95% Confidence Interval	p-value
Healthy: Overweight/Obese Grams of Sugar	9.11 g	-2.00 g to 20.22 g	0.107
Healthy: Overweight/Obese Kilocalories	81.77 kcal	-1.17 kcal to 164.70 kcal	0.053

Table 21: Healthy weight versus Overweight/Obese: Mean difference between the response of children to the advertisements

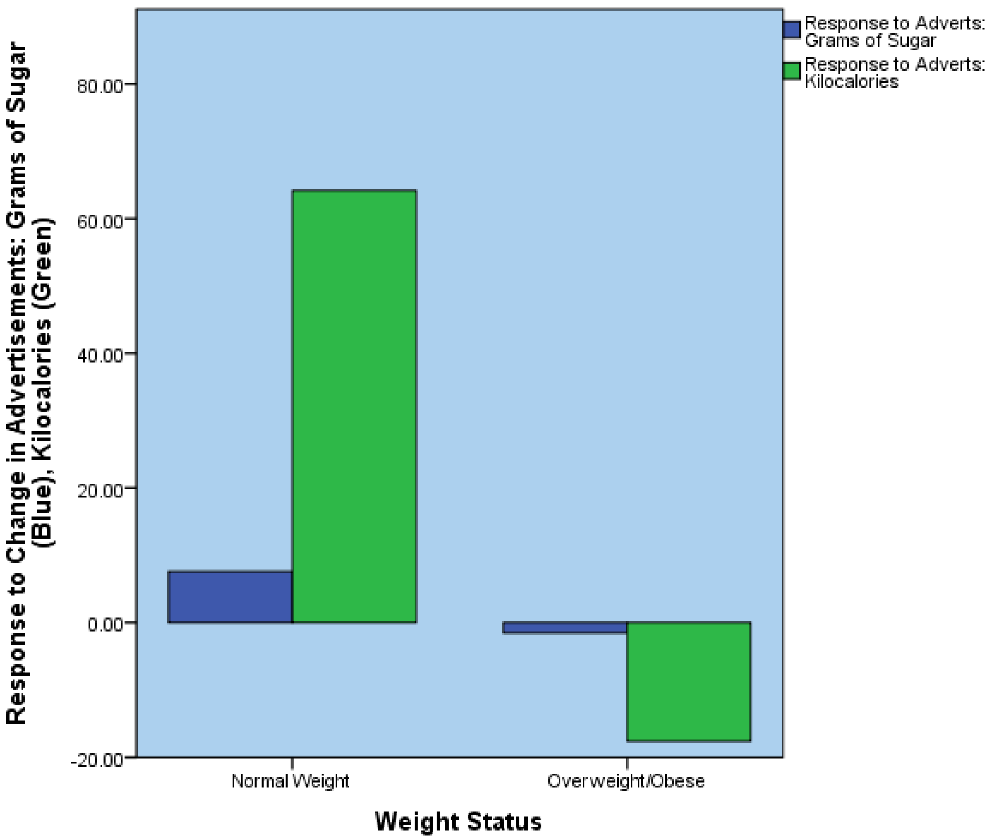

Figure 13: Influence of weight status on the children's response to the change in advertisements measured in grams of sugar and kilocalories

8.8 Influence of socioeconomic status on the children's response to the change in advertisements

To investigate the relationship between the children's socioeconomic status and their response to the advertisements (measured in both kilocalories and grams of sugar), one-way ANOVA was used. No statistically significant between group difference was found for either the children's intake of sugar ($p= 0.509$) or kilocalories ($p= 0.595$). However, it should be noted that the participants were predominantly IMD quintile 4 and 5 and as such is difficult to draw conclusions from the data. (See table 22 and 23, Figures 14 and 15)

IMD Quintile	N	Mean	Standard Deviation	Standard Error	95% Confidence Interval
1.00	2	-15.20	8.46	5.98	-91.22 to 60.81
2.00	3	-8.53	16.92	9.77	-50.55 to 33.50
3.00	6	13.33	20.81	8.49	-8.51 to 35.16
4.00	53	6.74	19.80	2.72	1.28 to 12.19
5.00	37	5.90	29.43	4.84	-3.92 to 15.71
Total	101	5.93	23.72	2.36	1.25 to 10.61

Table 22: Relationship between Socioeconomic Status (IMD Quintile) and the Children's Response. Measured in grams of sugar

IMD Quintile	N	Mean	Standard Deviation	Standard Error	95% Confidence Interval
1.00	2	-76.63	14.86	10.51	-210.17 to 56.91
2.00	3	-69.27	122.78	70.89	-374.28 to 235.75
3.00	6	93.26	166.49	67.97	-81.46 to 267.97
4.00	53	46.76	155.10	21.30	4.01 to 89.51
5.00	37	59.59	215.02	35.35	-12.10 to 131.28
Total	101	48.33	178.16	17.73	13.16 to 83.50

Table 23: Relationship between Socioeconomic Status (IMD Quintile) and the Children's Response. Measured in kilocalories

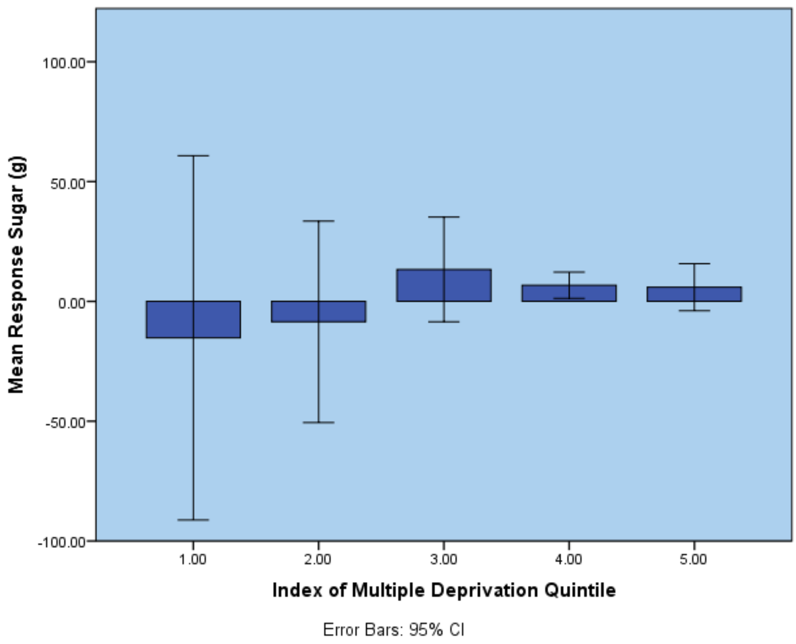

Figure 14: Relationship between Socioeconomic Status (IMD Quintile) and the Children's Response. Measured in grams of sugar

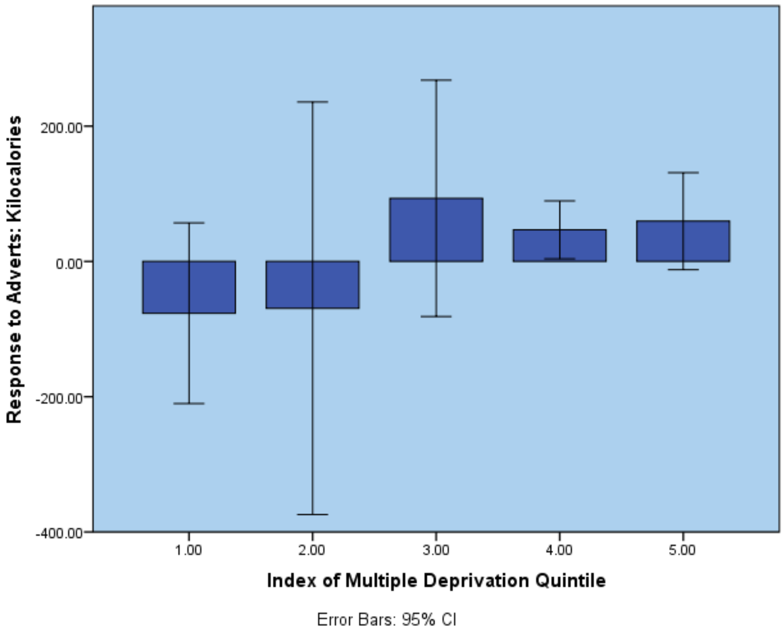

Figure 15: Relationship between Socioeconomic Status (IMD Quintile) and the Children's Response. Measured in kilocalories

8.9 Regression Analysis

Univariate linear regression analysis was undertaken with the children's response to the adverts as measured in kilocalories and grams of sugar set as dependent variables. The children's caries experience, weight status and socioeconomic status were potential independent variables.

As discussed earlier, independent variables were only included in the regression model if they were found to be associated with the dependent variables with a p-value of <0.2. As a result, weight status and caries status were included as the independent variables while socioeconomic status was omitted.

The results demonstrate that the association between dental caries status and the children's response to sugar was no longer statistically significant when regression analysis was undertaken (See tables 24 and 25).

Response to Advertisements: Sugar (g)	N	Unstand. B	95% Confidence Interval	p-value
Caries experience	99	9.70	-1.93 to 21.33	0.101
Weight Status	99	-8.98	-19.99 to 2.03	0.109

Table 24:Regression analysis: Dependent variable: Response to change in advertisements measured in grams of sugar. Independent variables: Caries experience and weight status.

Response to Advertisements: Kilocalories	N	Unstand. B	95% Confidence Interval	p-value
Caries experience	99	67.71	-19.24 to 154.66	0.125
Weight Status	99	-80.89	-163.25 to 1.48	0.054

Table 25: Regression analysis: Dependent variable: Response to change in advertisements measured in kilocalories. Independent variables: Caries experience and weight status.

8.10 Investigation of the relationship between the children's caries experience, their weight status and their socioeconomic status

To investigate an association between the children's caries experience, weight status and their socioeconomic status Pearson's Chi-Square tests were undertaken. No statistically significant association was found between any of the variables (See tables 26, 27 and 28)

IMD Quintile	Healthy weight N (%)	Overweight/Obese N (%)	Total N (%)	p-value
1	2 (2%)	0 (0%)	2 (2%)	
2	3 (3%)	0 (0%)	3 (3%)	
3	6 (6.1%)	0 (0%)	6 (6.1%)	
4	39 (39.4%)	13 (13.1%)	52 (52.5%)	
5	27 (27.3%)	9 (9.1%)	36 (36.4%)	
Total	77 (77.8%)	22 (22.2%)	99 (100%)	0.472

Table 26: Relationship between socioeconomic status and weight status. (Note: two children refused to be weighed)

IMD Quintile	No Caries N (%)	Caries N (%)	Total N (%)	p-value
1	1 (1%)	1 (0%)	2 (2%)	
2	3 (3%)	0 (0%)	3 (3%)	
3	4 (4%)	2 (2%)	6 (5.9%)	
4	43 (42.6%)	10 (9.9%)	53 (52.5%)	
5	30 (29.7%)	7 (6.9%)	37 (36.6%)	
Total	81 (80.2%)	20 (19.8%)	101 (100%)	0.622

Table 27: Relationship between socioeconomic status and dental caries experience.

	Healthy weight N (%)	Overweight/Obese N (%)	Total N (%)	p-value
No Caries	62 (62.6%)	18 (18.2%)	80 (80.8%)	
Caries	15 (15.2%)	4 (4%)	19 (19.2%)	
			99 (100%)	0.891

Table 28: Relationship between dental caries status and weight status.

9 Discussion

The primary aim of this study was to investigate if 8 to 10-year-old children make different food and drink choices, as measured by sugar and kilocalorie consumption, after watching a cartoon with advertisements for cariogenic food and drink products when compared to the same cartoon with advertisements for toys.

The results of this within-subject cross-over randomised controlled trial, demonstrate a statistically significant difference. Children consumed more sugar and more kilocalories after the cartoon with advertisements for cariogenic food and drink items. The results of our trial are consistent with the findings of Boyland *et al's*[12] systematic review and meta-analysis which concluded that "acute exposure to food advertising increases food intake in children".

Of Halford *et al's* three within-subject trials[11,14,146], two trials[14,146] measured children's intake of kilocalories. In their 2007 trial[14], the authors had a sample size of 93 children aged from five to seven years old. The children were shown ten 30-second advertisements prior to a 10-minute cartoon. The advertisements were for either food or non-food products. They were then given a selection of food items to eat including rice crackers, jelly sweets, chocolate buttons, ready salted crisps and green grapes. There was no time constraint for consumption of food. Following the advertisements for food products, the mean consumption was 667kcal (+/- 272.7). Following the advertisements for non-food products, the mean consumption was 559.3kcal (+/- 196). Thus, the mean difference between the two conditions was 107.7kcal.

In Halford et al's 2008 trial[146], a similar method was employed with 59 children aged from 9 to 11 years old. Following the advertisements for food products, the mean consumption was 604.6kcal (+/- 202.8). Following the advertisements for non-food products, the mean consumption was 295.9kcal (+/- 121.5). Thus, the mean difference between the two conditions was 308.7kcal.

In Dovey *et al's* 2011 cross-over trial[13], 66 children aged 5 to 7 years old were each exposed to three experimental conditions. The intervention was a 14-minute-long cartoon with a two-minute advertisement break at the midpoint. The advertisements were for healthy foods, unhealthy foods or toys. Following the cartoon, children were given 15 minutes to consume food. The foods provided were rice crackers, jelly sweets, chocolate buttons, ready salted crisps, green grapes and carrot sticks. Following the advertisements for unhealthy food products, the mean consumption was 461.2kcal (+/- 52.8). Following the advertisements for non-food products, the mean consumption was 400.3kcal (+/- 50.2). Thus, the mean difference between the unhealthy food condition and the non-food advertisements was 60.9 kcal.

In the current trial, children consumed 566.35kcal (+/- 229.90) following the cartoon with cariogenic food and drink products. Following the advertisements for non-food and drink items the mean consumption was 518.02kcal (+/- 255.73). This led to a mean difference of 48.33 kcal. This mean difference between the conditions is similar to, although slightly less than Dovey *et al's* results[13]. However, the size of the effect is substantially less than that reported by Halford *et al* in both of their trials[14,146]. The reason for this may be due to variation amongst the interventions. In Halford *et al's* trials[14,146], the children were exposed to ten 30 second advertisements and a ten-minute cartoon. Therefore, there was a 1:2 ratio between the time spent watching the advertisements compared with the cartoon. In Dovey *et al's* trial[13], this ratio was 1:7 and in the current trial it was 1:10.5. As such it could be argued that the effect of the advertisements was diluted as this ratio decreased. Regardless, it should be remembered that an increased daily intake of only 46 kilocalories is sufficient to lead to weight gain[38].

In the UK, ITV, Channel 4 and Channel 5 show an average of seven minutes of advertisements per hour with a maximum of 12 minutes in any one hour[159]. Thus, the ratio of advertisements to television programming supersedes the UK average in Halford *et als'* trials. In Dovey *et al's* trial and the current trial the density of advertisements is closer to the UK average.

Alternatively, as the advertisements shown in the various trials were different, it is possible that the advertisements utilised different and/or more effective persuasive techniques. A systematic review of persuasive marketing techniques to promote food to children on television techniques found that the use of premium offers, promotional characters, health and nutrition claims and themes relating to taste and fun were the most commonly employed techniques[160].

Our results are not consistent with those reported by Gatou *et al*[151] who also focused on cariogenic food advertisements and preference for cariogenic food. The authors reported that the exposure of children to food advertisements did not significantly affect their short-term preference for unhealthy foods. It is likely that this discrepancy is due to Gatou *et al*[151] measuring food preference through self-reported liking for images of food as opposed to actual food intake. This theory is supported by the fact that a similar within-subject trial by Boyland *et al*[154] which used images of healthy and unhealthy food and drinks as a tool for children to design a meal, also found no statistically significant difference.

The results of our trial demonstrate a statistically significant difference regarding the amount of sugar consumed by the children between the two exposures. Children consumed more sugar after watching the advertisements for cariogenic food and drink advertisements. There is limited evidence with regards to the effect that advertising has on children's dietary preferences with regards sugar intake. While many trials have included high sugar foods as the "unhealthy" food option[13,14,146], there has been no quantification of the sugar consumed. Although hypothetical in terms of intake, in Boyland *et al's* trial the authors did quantify the sugar in the meals designed by each child following exposure to the two conditions[154]. The authors report that no significant difference existed in the sugar content of the meals designed after watching the food advertisements compared with the non-food advertisements.

It is possible that the significance of our results regarding sugar intake reflects the food and drinks provided. The children were offered high sugar food and drinks and low sugar alternatives. Were a food type which is unhealthy but not high in sugar offered, such as crisps, it would test the hypothesis that cariogenic advertisements create a preference for cariogenic foods rather than unhealthy foods advertisements creating a preference for unhealthy foods.

The secondary aim of our study was to establish if a relationship exists between the children's response to the advertisements and the children's experience of dental caries, their weight status and their socioeconomic status. There is very limited evidence with regards an association between children's experience of dental caries and their response to advertising for cariogenic food and drink products[151]. It is possible that some children are inherently more susceptible to the effects of cariogenic food advertising than others. If this were the case, we would expect them to consume a greater amount of sugar in response to advertising. In turn, this increased sugar consumption would predispose them to dental caries. Our results demonstrated a statistically significant relationship between the children's response to the advertisements, in terms of sugar consumption, and their experience of dental caries.

It is possible, but extremely unlikely that the dynamic of the relationship observed is due to caries creating a predisposition towards a greater response to advertising. In fact, we would expect that the development of dental caries would cause children to become more aware of the consequences of excessive sugar consumption through oral hygiene instruction and professional preventative measures.

In addition, it should be noted that the acute consumption of a greater amount of sugar does not necessarily predispose to dental caries. Instead, we must extrapolate that the children that consumed a greater amount of sugar have developed dental caries as they also habitually consume sugar more frequently. Despite this study being an investigation of the acute effect that advertising has on children's dietary choices, it may represent a microcosm of what children experience throughout the day and through a variety of media[12].

The significance of this relationship was lost when regression analysis was undertaken with caries experience and the children's weight status set as independent variables and their response to the advertisements in grams of sugar as the dependent variable. This loss of significance appears to indicate an association between the independent variables, weight status and cares experience. However, this was not found to be the case. As such two possible explanations for the loss of significance are proposed:

1) The weak nature of the association, meaning that even the feintest association between caries experience and weight status resulted in loss of significance
2) The removal of the two participants who refused to have their weight taken affected findings. As regression analysis requires complete data for all included individuals, the 2 who refused to have their weight measured would have had their corresponding caries and intake values removed from the analysis.

To test the possibility of the second scenario being true, an independent sample t-test was undertaken to test for an association between caries experience and the children's response to the advertisements in grams of sugar, omitting the two students that declined to have their weight measured (See table 29 and 30).

	N	Response to Change in Advertisements: Grams of Sugar
No Caries Experience	80	3.67 g
Have Caries Experience	19	13.50 g

Table 29: Influence of the children's caries experience on their response to the advertisements measured in grams of sugar. Data from the two children who declined to have their weight taken has been omitted.

	Mean Difference	95% Confidence Interval	p-value
No Caries: Caries Sugar (g)	9.83 g	-21.55g to 1.89g	0.099

Table 30: Mean difference between the response of children with caries experience and without caries experience. Data from the two children who declined to have their weight taken has been omitted

With regards the two children omitted from the regression analysis, one child had caries experience and one did not. However, the response of the child with caries to the change in advertisements was amongst the highest in the study.

As such, the loss of significance during the regression analysis confirms both assertions. Firstly, the loss of data from the two children who refused to have their weight status measured did have an effect. In addition, the fickle nature of the association has been demonstrated through the loss of significance caused by omitting the two children's data completely.

With regards to an association between the children's weight status and their response to the advertisements, no statistically significant association was found. Although not significant, the overweight/obese had a reduction in intake from the toy to cariogenic food and drink advertisements. While the healthy weight children had an increase in intake from toy to cariogenic food and drink advertisements.

There is conflicting evidence regarding an association between children's weight status and their response to unhealthy food advertisements. Of the four similar within-subject trials[11,13,14,146], two found a statistically significant association while two did not. The two studies which report an association were both by Halford *et al*[11,146].

In their 2004 study, Halford et al report that all children, regardless of their weight status, consumed significantly more food after exposure to unhealthy food advertisements when compared with non-food advertisements. Furthermore, this effect was exaggerated in the overweight and obese children when compared with the healthy weight children.

The presence of an association between children's weight status and their response to unhealthy food advertisements was reinforced by the results of Halford *et al's* 2008 trial. The authors report a clear association with obese children increasing their kilocalorie intake by 471 kcal in response to the unhealthy food advertisements compared with the non-food advertisements. This is compared with an increase of 306 kcal for the overweight children and 250 kcal for the healthy-weight children.

In contrast to these two trials, a further trial by Halford *et al*[14] reported no statistically significant association between the children's weight status and their response to the change in advertisements. The authors suggest that this lack of significance may stem from the fact that these acute within-subject trials do not account for the amount of television watched by the children, nor the amount or type of advertisements they are exposed to in everyday life. As such, the acute exposure in these trials may be less impactful on the overweight/obese children due to it being relatively minor in relation to their total exposure. This lack of a significant relationship was also reported by Dovey *et al*[13].

The children in both trials which found a significant association between the children's weight status and their response to the advertisements were aged 9-11 years of age. In the two trials that found no significant effect, the children were aged 5-7 years of age. In our trial the children were aged 8-10 years of age. As such it is possible that the children's age plays a role in the physical manifestation of the effects of advertising[161].

Despite the lack of statistical significance, it was interesting that the results of our study demonstrate that the overweight/obese children had a reduced mean difference to the advertisements when compared with the healthy weight children. In addition, for kilocalories intake, the p-value was 0.053 meaning it was close to being significant. It is possible that the advertisements served as a trigger for self-consciousness in the overweight and obese children. Unlike dental caries, being overweight or obese is an instantly recognisable condition. School aged children are also more likely to be the victims of bullying behaviour if they are overweight or obese[7]. The advertisements may, in effect, have been a cue for self-restraint and this would account the overweight/obese children consuming less following the advertisements for unhealthy food and drink items when compared with the advertisements for non-food items.

We also investigated an association between the children's socioeconomic status and their response to the change in advertisements. Our results demonstrated no statistically significant difference between the children's IMD quintile and their response to the advertisements as measured in kilocalories or grams of sugar. None of the within-subject trials or between-subject trials measuring food intake identified in our literature review explored this relationship. However, in Gatou *et al's* trial[151], the authors did include an assessment of socioeconomic status. Socioeconomic status classification was based on parents' education and occupation, according to the criteria of the European Society for Opinion and Marketing Research[162]. The authors found no statistically significant association between the children's socioeconomic status and their response to the advertisements in terms of a preference for images of healthy or unhealthy foods.

Although not statistically significant, the results of our study do demonstrate differences between IMD Quintile 1 and 2 compared with IMD Quintile 3,4 and 5. However, it should be noted that very few participants were IMD Quintile 1 and 2 (two and three participants respectively). As such, these findings should be interpreted with caution.

Previous research has reported a relationship between children's gender and their response to the advertisements[147]. As such, we tested for a relationship in our cohort of children. Our results demonstrated that while boys ate more than girls under both conditions and had a greater mean response to the advertisements in terms of sugar intake and kilocalorie intake, the difference was not statistically significant.

No similar within-subject trial reports on the impact that gender may have on the children's response. However, of the between-subject trials found in our literary search, the studies by Anschutz *et al*[147] do refer to differences in response between males and females. In their 2009 trial[147], Anschutz *et al* report that food intake in boys was higher when they watched food advertisements compared with non-food advertisements. However, an inverse response was noted for girls leading to the authors conclude that boys are more susceptible to food cues in advertisements. Alternatively, Anschutz *et al*[147] theorise that girls may be more likely to inhibit the tendency to eat in response to food cues. Finally, the authors suggest that the content of the advertisements may have been focused more on boys than girls.

A later study by Anschutz *et al*[148] found no statistically significant difference between the response to the change in advertisements in boys and girls. This finding of no statistically significant difference is supported by the results of a study by Harris *et al* published in 2010[149] which reported that gender had no significant interaction with the children's response to the advertisements.

Finally, a third study by Anschutz *et al*[163], this time examining the effect of advertising on young adults, reported contrary results. In this study, the authors found that food intake was higher in women when they watched the food commercials than when they watched the neutral commercials. Meanwhile, food intake in men was lower when they watched the food commercials than when they watched the neutral commercials. These conflicting results may be due to age related variations, alternatively they may reflect the conditions that the subjects were exposed to.

Due to conflicting results from other trials, and the lack of significance in our trial, we cannot make any conclusions regarding a possible association between gender and children's acute response to unhealthy food and drink advertising.

9.1 Limitations

Before offering definitive conclusions based on the results of our study, it is important to acknowledge the limitations of our study.

With regards to the design of our study, a formal sample size calculation was not undertaken. Instead, we based our sample size on previous similar study conducted at the University of Liverpool[14]. This study had found a statistically significant difference between the children's kilocalorie intake in response to the change in advertisements conditions. It is of course possible that the referenced trial was underpowered itself which could have resulted in our trial being underpowered. As no previous trials have investigated the effect that cariogenic food and drink advertisements have on sugar intake, it was not possible to undertake a formal sample size calculation based on sugar intake. Despite this, our trial did demonstrate a significant difference in the children's sugar intake and our results can be used for the purposes of a sample size calculation in future trials.

During this trial, we measured the amount of sugar that children consumed with a view to relating this to their dental health. However, it is widely appreciated that it is not how much sugar that is consumed per sitting but rather the frequency of consumption which is detrimental to dental health[76]. As such, it is necessary to make the assumption that the same stimulus that leads to the children consuming more sugar in our acute setting trial also results in more frequent sugar consumption in their daily lives. Clearly, due to the difficulty in controlling children's exposure to advertising and monitoring their food and drink intake over a prolonged period, it would be difficult to definitively test for an association between the advertising for unhealthy food and frequency of sugar consumption.

Another potential limitation of this trial is the dental assessment. Since the children were at a developmental stage where they were losing deciduous teeth naturally, it was impossible for us to know if these teeth had been affected by dental caries or if they had been lost due to dental caries. Attempting to elicit this based on a discussion with the children or by subjectively estimating the child's state of dental development would have introduced unnecessary bias. The four first permanent molars erupt between the ages of 6 and 7, we felt that it was appropriate to limit the examination to these four teeth- thus mitigating the subjective decision with regards to the caries status of exfoliated baby teeth. However, by limiting our examination to the first permanent molar teeth, we had to accept the potential disparity in terms of how long the teeth had been erupted for. The children were aged 8.8 to 10.76 years old. As a result, some children may have had their first molar teeth for under 2 years while others may have had their first molar teeth for over 5 years. Despite this potential disparity, in the presence of a cariogenic diet, two years is sufficient for dental caries to form and it is likely that at 5 years post eruption that teeth in a cariogenic environment would either have been filled or extracted due to dental caries. In addition, although it would have been unethical, it is likely that radiographs would have allowed us to diagnose additional caries.

With regard to the trial setting, this trial was undertaken at a single school with a relatively homogenous IMD. As a result, it is possible that the results in other schools with different demographics may result in alternate findings.

With regards to the food and drinks used in our study, none of the advertised foods were provided. This was because we were not interested in the ability of advertisements to persuade children to consume a specific product. Instead, we were interested in the beyond-brand effect that advertisements for cariogenic food and drink items may have on children's dietary intake. To avoid brand recognition, we placed all food and drink items in generic containers. Despite this, some of the advertised products were similar to the food and drink items provided. The chocolate biscuits advertisements may have directly impacted on the children's consumption of chocolate buttons, the Starmix advertisement may have increased the consumption of fruit jellies and the Fanta orange advertisement may have had an impact on the consumption of orange juice.

A further potential limitation of our trial is the use of orange juice from concentrate as the high sugar drink. During the trial, some children voiced a dislike for the orange juice from concentrate. This would most likely have affected their intake of the orange juice. Despite this, as we were measuring the difference between their intake of orange juice between the two exposures, this should not have affected the nature of our results. However, it is the authors contention that this dislike of the orange juice from concentrate may have overcome the children's drive to consume sugar. This, in turn would have diminished the difference found between the two exposures. Had we provided the children with an alternative, more popular high-sugar drink, it is possible that a more profound and statistically significant effect may have been realised.

It is important to acknowledge the controlled conditions under which the trial was conducted. At home, it is likely that children would have consumed food and drink during the cartoon as well as after the cartoon. In addition, it is likely that children's eating behaviour is different at school than in the comfort of their own homes. As it is impossible to replicate the children's at home conditions, it is unlikely that we will ever discover the true effect that this may have.

Finally, as is the case with any repeat-testing trial, it is possible that the first exposure may have had an impacted on the second exposure. This may have been by generally increasing intake, as children knew that they would be getting sweet food. Alternatively, the novelty may have worn off and intake may have generally decreased. To test for this, we compared the children's intake during the first week to their intake during the second week regardless of the advertisements they viewed. As the mean difference between the two weeks was extremely small (8.5 kcal and 1.3g of sugar), it appears that the 2-week wash out period was sufficient.

9.2 Implications of Results

The results of this study will be of interest to medical professionals, dental professionals and policymakers as well as parents and childcare providers.

For medical professionals, the beyond brand effect of high sugar food and drink advertisements in terms of kilocalorie and sugar intake, should be of concern as it is potentially detrimental to children's health. As highlighted by the World Health Organisation, excessive consumption of free-sugars is a key factor in the growing childhood obesity epidemic[2]. As discussed earlier, the aetiology of childhood obesity is complex and is likely to be due to a combination of behaviour, environmental and biological factors. As such, it is unlikely that a simple solution exists. Certainly, the restriction of television advertising to children alone will not solve childhood obesity. However, it is likely that creating a healthier environment for children, including the restriction of unhealthy food advertising to children, will help in the fight against childhood obesity.

Furthermore, medical professionals are often required to advise parents on methods to prevent of manage childhood obesity. The practice of evidence-based medicine is now expected of all practitioners. As such, evidence from trials such as the current randomised controlled trial, form the cornerstone of clinical practice. This trial, along with many other similar trials, can be referred to when advising parents on the pitfalls of eating or snacking immediately after or while watching television.

This trial strengthens the argument for placing restrictions on children's television viewing habits. Our finding of an association between children's response to unhealthy food advertising and children's experience of dental caries is concerning. Dental caries has the potential to cause significant distress, pain, infection and even hospitalisation[67]. As such, when medical professionals are advising parents of the harmful effects of television viewing, this trial adds valuable evidence to the argument for placing restrictions on viewing habits.

For dental practitioners, the harmful effects of unhealthy food advertising on children's dietary intake may be new information. However, our finding that the advertising of cariogenic food and drink products can affect children's intake of sugar is very interesting.

As a profession, dentists strive to raise awareness of the harmful effects of excessive sugar consumption. Solutions are usually limited to advising parents to restrict children's access to harmful food and drinks. However, the results of this study should raise awareness of the role that children's environment may play in dental caries development. Dentists are perfectly placed to provide preventative advice regarding restricting children's television viewing habits. In addition, as in medicine, dentists are encouraged to take an evidence-based approach to practice. This study provides the necessary evidence for dentists to make recommendations to parents with regards to the potential for unhealthy food and drink advertising to damage their children's dental health.

The publication by the World Health Organisation of guidelines[2] regarding sugar intake for children and adults has placed an onus on governments to implement policies to address excessive sugar intake. Furthermore, the WHO's recognition of the deleterious effect that children's exposure to unhealthy food and drink advertising can have has led them to urge member states to restrict advertising aimed at children.

In the UK, the government must be commended for acting on this evidence. However, as discussed in section 6.4.6, the restrictions placed on advertising do not appear to have had the desired effect of reducing children's exposure to high sugar food and drink advertisements. As a result, there has been pressure to tighten these restrictions, including calls for the Government to extend restrictions to 9pm[164].

The current research should serve to strengthen calls for further restrictions to be placed on advertising to children. In addition to confirming the findings of previous research regarding the beyond-brand effect that television advertising has on children's dietary intake, our study has produced novel results with regards the ability of cariogenic food and drink advertising to affect sugar intake. Furthermore, an association between children's response to cariogenic food and drink advertising and their experience of dental caries is worrying as it suggests that children that are more susceptible to the effects of advertising are at a higher risk of dental caries. With the WHO's guidelines and recommendations in mind, this study should be considered in any future policy development.

Finally, for parents and the providers of childcare, this trial should be of interest as it highlights the potential detrimental effects of cariogenic food and drink product advertising.

Implementing simple “house-rules” such as limiting snacking while watching television may help in the battle against childhood obesity and childhood dental caries. Through the dissemination of our results of this trial, we hope to empower parents and childcare providers with the knowledge required to create a healthy environment for their children.

10 Recommendations for Further Research

Despite every effort to ensure the robustness of the current trial, there are still questions which remain unanswered. In addition, based on the knowledge and experience gained, there are elements of this trial that we would change if we were repeating it. It is hoped that by sharing our experiences and suggesting solutions, that future research can answer some of the unanswered questions which remain.

Firstly, with regard the sample size, future research investigating children’s response to high sugar food and drink advertisements could use our results to conduct a formal sample size calculation based on sugar intake.

Furthermore, as mentioned in our limitations, the use of a more appropriate high sugar drink such as Fruit-Shoot™ or a soft drink may have been more appropriate. It is the authors contention that the dislike of the taste of orange juice may have overcome the drive to consume sugar from the orange juice. This probably did not affect our overall results, as children could satiate the drive to consume sugar by eating the high sugar foods. However, it is likely that it affected our results with regards to the consumption of high sugar drinks in isolation.

To the best of the authors knowledge, this trial was the first randomised controlled trial to investigate an association between children’s socioeconomic status and their response to unhealthy food and drink advertisements. Our finding of no significant association may be valid or it may reflect the method of assessing socioeconomic status. For instance, it is possible that using an alternative individual-centred method of assessing socioeconomic status, such as parental level of education or occupation may have given different results. As such, we would require replication of our findings in other populations and perhaps with alternative tools before we can draw firmer conclusions. In addition, it should be noted that the children in our study came from one region and as such we did not have equal representation of the IMD quintiles.

The results of our trial failed to demonstrate a statistically significant association between the children's weight status and their response to the cariogenic food and drink advertisements. As the existing evidence has produced conflicting results this is certainly an area which requires further investigation.

Similarly, our trial found no difference between the response of boys and the response of girls to the cariogenic food and drink advertisements. As with weight-status, there is conflicting evidence regarding this area and it this would also warrant further investigation.

This study was the first trial to demonstrate a statistically significant association between the children's response to cariogenic food and drink advertisements and their experience of dental caries. As this is a new finding, replication of these findings in a different population would be of interest. Furthermore, it would be interesting to undertake a similar trial in a slightly older cohort, perhaps at 13 to 14 years old, when the children are in the permanent dentition and no curtailments of the DMFT Index is required due to children being in the mixed dentition.

Finally, this trial and a similar within-subject trials by Dovey *et al*[13] and Halford *et al*[11,14,146] have exposed children to the adverts either mid-cartoon or prior to the cartoon. All trials provide children with food after the cartoon is complete. This is not likely to be the case for children's snacking at home. It is more likely that they will snack while they are watching television. As such, it would be of great interest to undertake a similar trial with the children consuming food and drink during the television programme. This has been done for between-subject trials[147] and has allowed comparison of pre-advertising consumption for both trial conditions and post advertising consumption for both trial conditions.

11 Conclusions

The results of this cross-over randomised controlled trial demonstrate that:

1) Children consume more sugar and total kilocalories in response to watching cariogenic food and drink advertisements when compared to non-food/drink advertisements,
2) Children with experience of dental caries have a greater response to the change in advertisements with regards sugar intake than children with no experience of dental caries,
3) No significant association was found between the children's response to the change in advertisements and their weight-status or socioeconomic status,
4) No significant association was found between children's caries experience, weight status and socioeconomic status.

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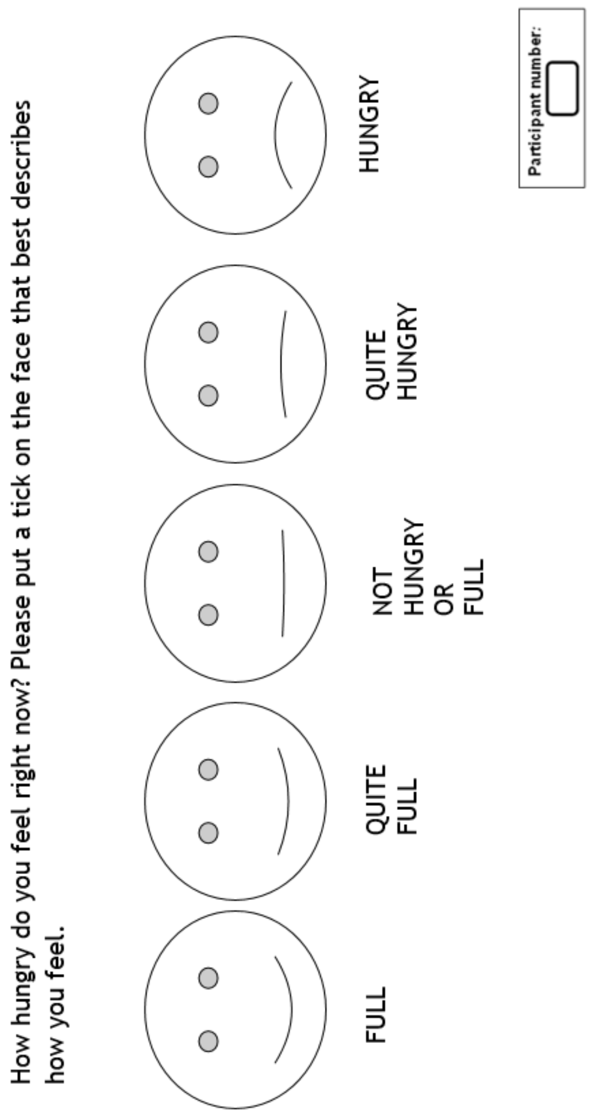
Appendix 1:


How hungry do you feel right now? Please put a tick on the face that best describes how you feel.
FULL
QUITE FULL
NOT HUNGRY OR FULL
QUITE HUNGRY
HUNGRY
Participant number:

Appendix 2:

Food Data Collection Form

Student Number (Sticker on Students Top):

Tray Number (Sticker on Tray):

	Water	Orange Drink	Green Grapes	Carrot Batons	Chocolate Buttons	Jelly sweets
Weight Before						
Weight After						

Appendix 3:

BMI

Student/Participant Number:

Height (cm)	
Weight (kg)	

Appendix 4:

Dental DMFT

Student/Participant Number:

Dentist Name:

Tick the appropriate box(s):

Tooth	Decay	Missing	Filled/Crowned
UL6			
UR6			
LL6			
LR6			